EFFECT OF TREATED OIL REFINERY WASTE WATER ON PHYSIOMORPHOLOGICAL CHARACTERISTICS OF TRITICALE

ABSTRACT

THESIS

SUBMITTED FOR THE DEGREE OF

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IN

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DEPARTMENT OF BOTANY
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EFFECT OF TREATED OIL REFINERY WASTE WATER ON PHYSIOMORPHOLOGICAL CHARACTERISTICS OF TRITICALE

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Abstract of the Thesis, Submitted to the Aligarh Muslim University, Aligarh, India, for the Degree of Doctor of Philosophy in BOTANY, 1991.

Four split plot field trials on triticale (cv. Delfin, Driera, TL-419) were conducted at the Experimental Farm, Mathura Refinery, Indian Oil Corporation, Mathura (India) during rabi seasons of 1988 - 1991. The aim of the trials was to study the effect and utility of treated effluent on germination, growth, yield and quality charateristics of triticale. Ground water and wheat (cv. HD-2204) were taken as checks. The data were mostly found significant.

In Experiment 1 (1988-89) the effect of treated effluent was studied on germination, growth, yield and quality of triticale. Ground water and wheat were taken as checks. For growth and yield attributes and yield, treated effluent proved better than ground water. On the other hand, grain quality was advesely affected by treated effluent irrigation, Among the cultivars tested, Delfin outyielded other triticale cultivars as well as the wheat check. In general, triticale possessed higher protein, carbohydrate and lysine content

than wheat.

Experiment 2 was performed in 1989-90 to study the effect of various levels of treated effluent irrigation (I_0, I_1 I_2, I_3 and I_4) on growth, yield and grain quality of triticale (cv. Delfin). Ground water was taken as check. Again treated effluent proved superior over ground water. I_3, under treated effluent irrigation, and I_4 under ground water irrigation, proved best for growth and yield. Water stress (I_0), in general, decreased all the growth, yield and qualaity parameters.

Experiment 3 was conducted during the year (1990-91) on triticale (cv. Delfin) to study the interaction of three levels of potassium (0, 30 and 60 kg. K/ha) and four levels of irrigation (I_0, I_1, I_2 and I_3) under treated effluent irrigation. Potassium showed significant increase in all the growth and yield attributes including grain yield. Three irrigations together with K_{60} proved best. Relative water content and proline content were also increased by potassium application.

Experiment 4 was conducted simultaneously with Experiment 3 (1990-91) on triticale (cv. Delfin) and wheat (cv. HD-2204) to study the effect of four doses of fertiliser ($N_0P_0K_0$,$N_{60}P_{30}$ K_{30}, $N_{90}P_{45}K_{45}$ and $N_{120}P_{60}K_{60}$) cultivated under treated effluent irrigation. Delfin proved superior over wheat in respect of growth, yield and grain quality. $N_{120}P_{60}K_{60}$ proved optimum for all the growth yield and quality charactertics, except lysine content.

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CERTIFICATE

This is to certify that the thesis entitled "**Effect of Treated Oil Refinery Waste Water on Physiomorphological Characteristics of Triticale**" submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Botany,** a faithful record of bonafide research work carried out at the **Experimental Farm, Mathura Refinery, Indian Oil Corporation, Mathura** and **Aligarh Muslim University, Aligarh** by **Mr. Ozair Aziz** under my guidance and supervision and no part of it has been submitted for any other degree or diploma.

Arif Inam
(Supervisor of Research)

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CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Water is a major constraint in crop production as it induces a series of metabolic and morphological changes in the plant (Turner, 1979; Hsiao and Bradford, 1983). It is well known that water stress profoundly affects photosynthesis (Boyer, 1976; Osmond *et al.,* 1980). Both relative water content and leaf water potential serve as indicators of plant water status (Hsiao and Bradford, 1983). Water stress decreases the synthesis of proteins as well as carbohydrates which are the main components of cereals(Levitt, 1980)

The Science Advisory Council of Government of India has cautioned that, if food production is not raised to 300 million tonnes by the end of this century, there would be unimaginable food crisis. The target seems to be too ambitious and may be difficult to achieve mainly because it would largely depend on expanding the area under cultivation and increasing productivity in terms of yield per hectare. The latter strategy depends on high inputs in respect of quality of seeds, fertilisers, pesticides and above all, irrigation, which are cost intensive. However, there are possibilities that food production could be increased through improved dryland farming and by undertaking cultivation under adverse agro-climatic conditions. The farmers are rightly being encouraged to utilise all available land and to irrigate it even with sub- standard water, at least in those areas where water is scarce.

As long as the human population was small and scattered over large areas of land, the disposal of human wastes created no problems but, with rapid increase in population and urbanisation, the problem of the pollution of natural water bodies is reaching an alarming proportion. It has been further intensified by industrialisation on the banks of rivers and other water bodies where water is readily available. Cities and industries discharge their untreated or partially treated sewage and industrial wastes into neighbouring water bodies. The latter thus get polluted and become unsuitable as sources of potable water and even for industrial water supply.

Waste water treatment developed in rich and technologically advanced countries is highly mechanised and energy consuming and is neither appropriate nor financially justifiable in developing countries. The development of simple low cost processes, coupled with re-use of the effluents in agriculture, offers the most suitable solution, such a solution, while solving the problem of water pollution, simultaneously conserves the water resources as well as the fertilising components of sewage and industrial waste. Thus, application of effluents on agricultural land could supply not only much needed water to growing crops but also manurial ingredients.

However, there are possibilities that application of large amounts of effluent on agricultural land may deteriorate the soil and, in the long run, render it unfit for cultivation, particularly due to accumulation of toxic elements, like heavy metals, so, it is necessary to work out irrigation schedules for the optimum production of each crop so that only the required amount of effluent is applied on the soil.

Among various nutrients, potassium has been found to be the most efficient in ameliorating crop losses under drought conditions. It promotes drought tolerance in crops through its well known role in the physiology and biochemistry of plants. It activates a number of key enzyme systems (Evans and Sorger, 1966; Suelter, 1970). It also lowers the osmotic potential of root cells and increases water uptake. This property of potassium could be exploited under conditions of restricted utilisation of waste water for crop production.

Among cereals, triticale, a hybrid of wheat and rye can tolerate adverse environmental conditions better than most other commonly grown crops. It may be pointed out that in the CIMMYT report (1985-86) it was suggested that triticale should be tested and cultivated in major dryland areas in the developing world, particularly North Africa and the Middle East, Central India, the dry areas of Afghanistan and parts of Sind and Baluchistan provinces in Pakistan (Anonymous, 1988).

Triticale is known to be well adapted to various regions and climates and to perform better than wheat in disease prone areas and semi-tropical highlands. At present, it is grown in more than 500,000 hectares of land all over the world, including Argentina, Australia, Canada, China, Hungary, Kenya, Mexico, S.Africa, Spain and the USA. In countries like Brazil and India, this crop has been introduced recently (Anonymous, 1982). In India, its cultivar TL-419 has been released to the farmers of Punjab (Gill *et al.*, 1981; Abdalla *et al* 1986). At Aligarh, a lot of work has been carried out on the mineral requirement of triticale by Afridi *et al.* (1977); Inam (1978); Abbas (1980); Alvi (1984); Ashfaq (1986); Moinuddin (1987); Samiullah *et al.* (1987); Haque (1989 a,b,c); and Moinuddin *et al.* (1990 a, b).

In view of the known tolerance of triticale to various environmental adversities, the present author decided to utilise it so as to study the impact of treated oil refinery wastewater in relation to water stress, nutritional stress and water use efficiency of potassium.

The following four field experiments were therefore, conducted.

i) To compare the performance of three selected improved varieties of triticale in relation to germination, growth, yield and quality after being irrigated with treated effluent of the oil refinery and ground water, keeping wheat as check.

ii) To study the comparative effect of irrigation levels of treated effluent and ground water on the growth, yield and quality of one variety of triticale (Delfin), selected on the basis of its superior performance in Experiment 1.

iii) To study the interaction of refinery effluent and induced drought condition on the growth, yield and quality of Delfin with various levels of basally applied potassium.

iv) To study the impact of refinery effluent on the comparative performance of triticale and wheat with regard to growth yield and quality under varying levels of basally applied NPK.

CHAPTER 2

REVIEW OF LITERATURE

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CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

The study of plant response to various environmental conditions has been a central feature of environmental physiology. Attempts to understand the pattern of plant distribution and performance along environmental gradients like waste water application, water stress and nutritional stress have been made from time to time. In the present review, an attempt has been made to review the available literature with respect to various types of waste water, irrespective of their source of origin, their impact on the physiomorphology of different crops, water stress and its effect on plant, role of potassium in water use efficiency and brief history of triticale.

2.2 Waste water

Pollution of water started with the establishment of villages, towns and cities in the vicinity of water bodies, mainly lakes, springs and rivers. The by products and all kinds of filth from houses and communities got gradually transferred to different water bodies. Initially, the carrying and self purifying capacities of these water bodies were large and the discharge of by products small; but increasing population, concomitant industrial growth and increase in standards of living reversed the trend. Consequently, the quality of water deteriorated to such an extent that it impaired the legitimate use of water.

It may be pointed out that the earth today inhabited by more than 4.3 billion people and population is increasing at an alarming rate. Industrialisation has increased the use of chemicals in various forms and combinations many of which are carcinogenic - mutagenic. Approximately, 70,000 chemicals and their products are in daily use and 1,000 new chemicals are introduced every year. The industrial wastes from these industries, which are harmful to human beings as well as aquatic life, find their way into the water bodies. Large quantities of fertilisers and pesticides used for increased food production also find their way as residues in agricultural run off. In addition, paper factories, distilleries, fertiliser factories, dairies, oil mills, sugar mills, tanneries, and municipal waste further deteriorate the water sources. Ignorance and casual attitude on the part of villagers and uneducated group of urban population contribute additionally to increase in pollution. To make it worse, industries also have failed to do their bit in treating their wastes before discharging them into the nearby water channel. Such water pollution results not only in the deterioration of the quality of fauna and flora but also causes substantial loss to the national economy and also the aesthetic value of the surrounding.

The liquid wastes resulting from manufacturing and industrial processes which utilise moderate to large quantities of water are termed æIndustrial wastesÆ and the term is restricted to liquid wastes which by reason of their colour, solid content, inorganic content, salinity, acidity, alkalinity and other toxic characteristics create problems of water pollution (Mahida, 1981). While domestic sewage is almost always suitable for crop irrigation, the suitability of industrial wastes for such purposes cannot be taken for granted. Therefore, such wastes must invariably be analysed to ascertain their suitability for application on crop land. The ability of industrial waste waters to supply nutrients to crops must be regarded as of secondary importance. The possible deleterious effects of application of such wastes with regard to various soil conditions, therefore, need special consideration.

In judging the possible harmful effects of the application of industrial wastes on soils resulting from excessive concentration of salts, the intrinsic difference between irrigation and disposal of wastes on land must be carefully taken into account (Fig.1) A large proportion of water is dissipated by evaporation and transpiration. Only very limited quantities of salts are absorbed by the plants. There is, therefore, the tendency towards an increase in the concentration of salts in soil columns On the other hand, in schemes for disposal of waste water on land, the objective is to dispose off as large a quantity of waste water as possible on a limited acreage of land.

The toxic substances from amongst the chemicals which cause water pollution deserve special attention, irrespective of the relatively small amounts involved as their deleterious effect on organisms depends both on concentration and duration of exposure - low concentration over a long period

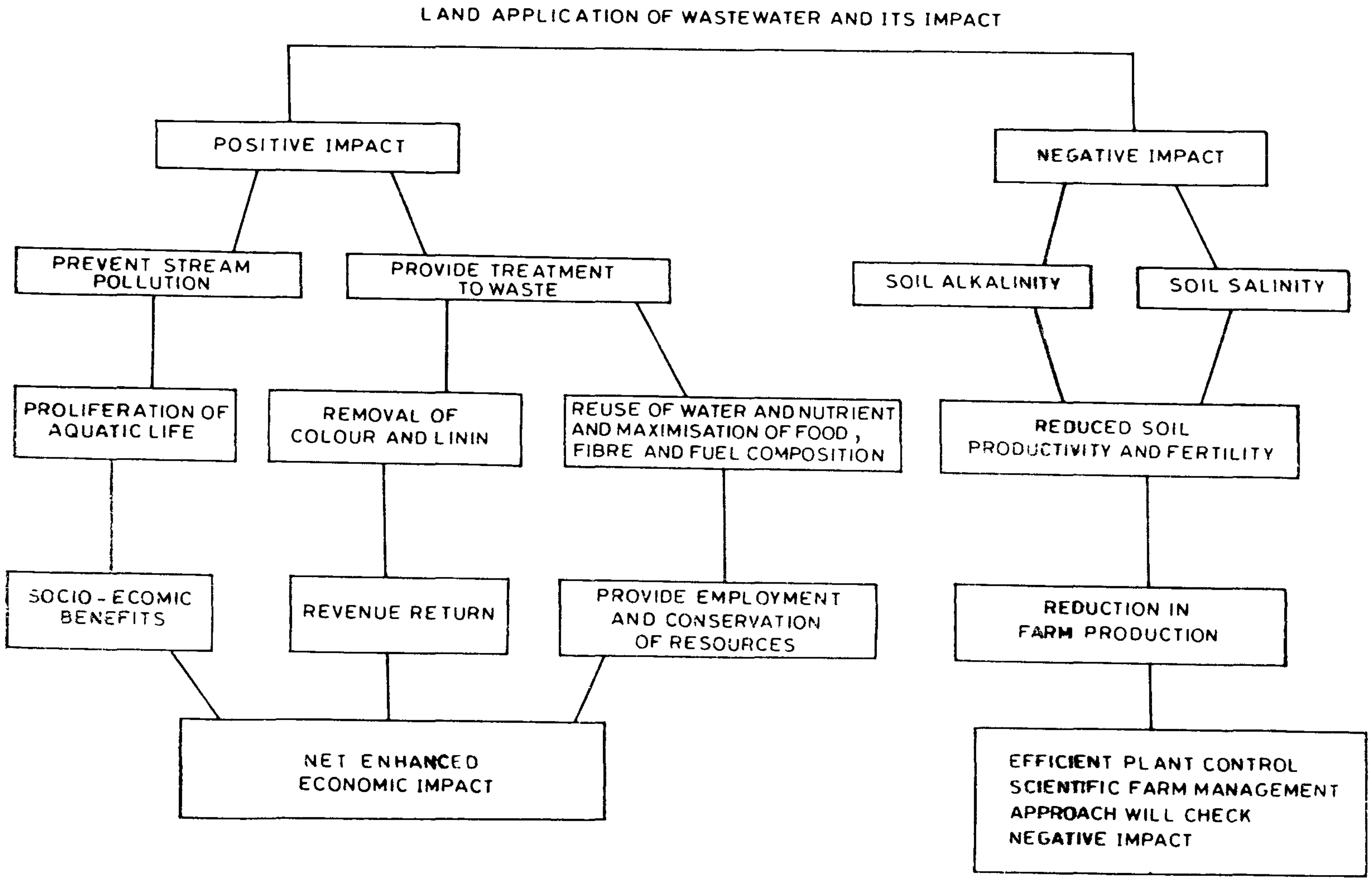

FIG 1 EFFECT OF WASTEWATER ON LAND

may have the same effect as high concentration for a shorter period. Another important property of living organisms is their ability to concentrate material within their tissues. Thus, substances which occur at such a low concentration in water as to pose no threat through direct toxicity may, if absorbed and accumulated, attain toxic level (Hellawell, 1988).

In India, the total waste water generated per annum and discharged mostly untreated from establishments in 142 class 1 towns alone is about 26,000 million cubic meters. As an example. Kanpur city of Uttar Pradesh, with 647 factories has treatment plants installed in only three factories. The rest dispose off about 200 million litres waste water and industrial effluents a day, straight into the river Ganges. A survey, conducted by the Central Board for the Prevention and Control of Water Pollution, New Delhi, indicates that about 65-70% of the waste water does not get any treatment. More or less the entire quantity of domestic and industrial effluents generated in our country is let into rivers, lakes and other water bodies. Renovation of this waste water through conventional treatment requires high energy input and is estimated to cost approximately 12,000 million rupees. In the National Water Policy, therefore, it was rightly pointed out that waste water (industrial and domestic) may be used in agriculture, due to its easy availability, to irrigate about 250,000 ha of land, thus providing an alternate source of water for irrigation for the production of food, fodder, fibre and fuel (Ramchandran and Ambujam, 1990).

In Arizona (USA), Day *et al.* (1975) studied the influence of treated municipal waste water on growth, yield, protein and amino acid content among other characteristics in wheat. They grew wheat with three irrigations and fertiliser treatments on two types of soil. Wheat was grown with well water plus suggested amounts of check revised 112 kg N, 35 kg P and 1 kg K/ ha from commercial sources in amounts equal to those found in waste water (224, 73 and 140 kg/ha of N, P and K respectively). They found that average number of heads per unit area and grain yield were higher in wheat plots that were grown with well water plus NPK. Plant height, seeds per head and seed weight were similar for three irrigation fertiliser treatments. They also observed that the grain grown with waste water contained more total protein than did grain produced with well water plus NPK. Wheat grain that received only waste water contained more alanine, histidine, isoleucins and proline.

Day and Tucker (1977) conducted another field experiment at Tucson (Arizona, USA) to study the effect of treated municipal waste water on growth, fibre, protein and amino acid content of grain in sorghum. They observed that, when sorghum was grown in Comoro sandy loam, average number of days from planting to maturity, leaf length and grain yield were higher in plots that received waste water than well water plus suggested amount of N.P and K. Sorghum grown with waste water produced more grain than that grown with synthetic waste water. They also noted that sorghum grown with all irrigation and fertiliser treatments contained similar amounts of total protein. In sandy loam soil, grain from sorghum grown with simulated waste water and waste water alone contained less cystine, glycine, and histidine than did grain produced with suggested culture. They further noted that grain grown with all treatments in both soils, contained similar amounts of leucine, methionine, threonine and tyrosine. They concluded that treated municipal waste water may be an effective source of irrigation water and plant nutrients for obtaining high yields of good quality sorghum grain.

Muthuswamy *et al.* (1977) conducted field experiments in the acidic soil of Nilgiri (Tamil Nadu) to study the influence of industrial and mineral wastes on dry matter and protein content of potato. They found that the dry matter content of potato tubers ranged from 19.35 to 23.88% and was not appreciably influenced by the different waste materials under trial. The percentage of crude protein in tubers that ranged from 9.78 to 14.19 was found to be significantly enhanced by application of floatation sludge and aglime which were at par.

Day *et al* (1979) at Arizona studied the effect of municipal waste water and pump water on wheat at Tucson (Arizona, USA). They noted that irrigation with mixture of pump water and waste water produced taller plants, more ears per unit area, heavier seeds and higher grain and straw yields than wheat grown with only pump water. They also noted higher soluble salts and nitrate nitrogen in soil irrigated with pump water + waste water mixture. However, the pump water+waste water mixture had higher levels of total N and P than did pump water alone. Extractable P was higher in soils irrigated with pump water + waste water mixture than in soils irrigated with pump water.

McAuliffe *et al.* (1979) in long trials for 15 years studied the effect of spray irrigation with dairy factory effluent on pasture in Palmerston (New Zealand). Effluent composition analysis revealed that large quantities of nutrients e.g. N and P had been applied to the site which resulted in marked increase in inorganic and organic fractions of these nutrients in the soil.

Palazzo and Jenkins (1979) in Hanover (USA) studied the effect of land application of waste water on soil and plant potassium content. They observed that the waste water contained more than twice as much N as K and the plant removal of K increased as the amount of N applied or removed by the forage increased. It was further noted that K fertilisation increased total plant yields and the concentration of this element in plants.

Rajannan and Oblisami (1979) studied the effect of paper factory effluent on soil and crop plants at Coimbatore (Tamil Nadu). The effect of the effluent on germination, vigour index of seedling, root length and shoot length of rice, blackgram and tomato were assessed. They found that the undiluted effluent affected the germination of all the three crops, however the diluted effluent did not inhibit the germination of seeds and growth of seedlings. The vigour index of all the seedlings of the three crop plants was significantly poor in undiluted effluent when compared to water control and increased with the decrease in the concentration of the effluent. They also found that rice tolerated the effluent effect much better than blackgram and tomato.

Wood *et al.* (1979) working in Malaysia, studied the land application of palm oil mill effluent. They reported an improvement in soil structure and nutrient status, the effluent acting as fertiliser replacement and, therefore, recording extra yield. However, they also noted some adverse effects on land application of raw mill effluent as it was responsible for clogging and water logging of soil and killing the vegetation on contact. They suggested that the adverse effect could be controlled by applying a small quantity at a time.

Marten *et al.* (1980) carried out field experiments at Minnesota in USA to study the effect of municipal waste water on the performance and feed quanlity of maize and reed canary grass. Effluent application increased crude protein of reed canary grass per hectare but not of maize. Perennial grasses showed superior capacity compared to maize for removal of N from soil treated with large amounts of waste water. The grasses were highest protein yielder per hectare, but at the same time the least digestible dry matter producers in effluent treated system. Both reed canary grass and maize could thus effectively renovate a large amount of waste water effluent applied to permeable soil.

Reynolds *et al.* (1980) studied the long term effect of waste water irrigation in Utah (USA). They observed that secondary effluent was of satisfactory quality for crop irrigation. No significant accumulation of Cd, Cr, Cu, N, Ni, Pb, and Zn could be attributed to the effluent irrigation. No harmful accumulation of heavy metals in alfalfa, grown at the effluent irrigated site, was noted.

Reddy *et al.* (1981) of Hyderabad (Andhra Pradesh) conducted exhaustive experiments on sugarcane separately with fresh water and effluent from an integrated pulp and paper mill. It was observed that the effluent could be used successfully for irrigation of sugarcane, especially on acidic coarse textured sandy loam soil, with about 20% increase in sugarcane yield without affecting the quality of cane as well as the soil. They concluded that irrigation with effluents offers an alternative to grow high yield variety of cane instead of the drought resistant low yield variety commonly grown in the area.

Ajmal and Khan (1983; 1984 a, b; 1985) carried out various studies at Aligarh (Uttar Pradesh) on the effect of industrial effluents on the germination and growth of a variety of crop plants. In addition to some heavy metals, the effluents were rich in Ca,Cl, K, Mg, Na, SO_4 etc and the values of COD and BOD were also high. They observed a general reduction in germination when the concentrations of effluents were 80 - 100% while germination was normal under 25-50% effluent concentration. They also noted that the undiluted and 75% effluent retarded the growth of plants while dilute effluents (25 to 50% enhanced plant growth.

Cordonnier and Johnston (1983) conducted a field experiment in

Georgia (USA) on soybean using municipal waste water, well water and no water to study seed yield, agronomic characteristics, dry matter production and photosynthesis. Seed yields were significantly different from water treatment with 2,430, 2,580 and 2,790 kg ha^{-1} for no water, well water and waste water respectively. They also noted that irrigated plants were 4-5 cm taller, matured 5-6 days later and had larger seeds. They concluded that under the conditions of soil type, climate and waste water quality obtaining during their experiment, waste water was generally superior to well water in increasing yields.

In another study conducted at Aligarh, Uttar Pradesh, Ajmal *et al.* (1984) observed the effect of industrial dairy processing effluent on soil as well as kidney bean and pearl millet. The effluent was slightly alkaline and had high BOD and COD and was also rich in bicarbonates and calcium. They found that soil irrigated with effluent showed an increase in pH, organic matter, calcium carbonate, water soluble salts, cation exchange capacity, electrical conductivity, nitrogen and phosphorus. They also monitored the effect of undiluted effluent and of effluent diluted to 25, 50 and 75% (using water as control) on the germination and growth of the two crops. It was observed that undiluted effluent restricted the germination of kidney bean to some extent while that of pearl millet was enhanced upto 100%. On the other hand, undiluted effluent retarded the height of plants of both crops while 25% effluent in kidney bean and 75% effluent in pearl millet enhanced it.

Effect of industrial effluents from a paper factory, an automobile industry, textile factory and food and paper industry on soil properties, seed germination and seedling growth have been studied by Somashekar *et al.* (1984) at Bangalore (Karnataka) The effluents contained excess of BOD, COD, dissolved solids, suspended particles, heavy metals and cyanides compared with the ISI standards. Effluent from paper mills almost completely inhibited the germination of paddy seeds even at 25% concentration. The inhibition of germination of jowar, bajra and paddy seeds in case of treatment with 100% effluent was 31.18, 37.5 and 82.19% respectively. The effluents of other industries were more or less similar in their effect on the parameters studied in this trial. The vigour index of the seedlings of all the three crop plants was significantly poor in undiluted effluents but increased as their concentration were decreased.

While working with maize cultivars, grown in pots, Stirban *et. al.* (1984) in Napoca studied the effect of two samples of nitrogen-rich waste water obtained from fertiliser factory, soil or liquid culture media and under normal field conditions. After applying various dilutions of waste water to the cultivar HD 100 supplied with urea-free waste water, increase in vegetative growth and grain yield was noted. The protein and lipid contents of the grains were also noted to improve. On the other hand, cultivar HD 213 showed poor response. In the same year, Pound *et al.* of Michigan (USA), recommended the use of municipal industrial waste water to produce useable crops.

Calero *et al.* (1985) in Cuba studied the waste water quality from a sugar mill and the feasibility to use it for irrigation purposes on the basis of electrical conductivity (EC), sodium adsorption ratio (SAR), magnesium index and sodium percentage. They evaluated the quality of waste water from four sources and concluded that unless waste water consisted of medium salinity there was no risk of sodification.

In USA, Hemphill *et al.* (1985) studied the effect of tannery waste on lettuce and broccoli. They noted an increase in soil pH, N, extractable Ca, B and total Cr content and reduction in soil extractable Mg and Fe content. Waste application had essentially no effect on soil Cu, K, Mn, Mo, Ni, P, Pb, S and Zn content. The nitrogen concentration of lettuce grown on waste amended soil was higher than that of lettuce grown on untreated soil. They also reported that the yields of both crops increased when grown on tannery waste amended soil.

Padmanabhan *et al.* (1985) studied the effect of seed hardening on growth and productivity in groundnut and finger millet under pulp and paper industry effluent irrigation at Coimbatore (Tamil Nadu). They found that effluent irrigation reduced the total dry matter at all the stages of growth and the reduction was more marked in variety MGS-7 as compared to KG-61-240 variety of groundnut. The pod number differed significantly due to effluent irrigation. Both pod weight and seed weight were also decreased and the differences were significant. In finger millet, significant reduction was observed in total drymatter on 45,60 and 80 days and at harvest in effluent irrigation. Significant reduction in leaf area index was observed due to effluent irrigation at all stages. They also found that in both the varieties of finger millet, tiller number, ear weight and grain weight decreased due to effluent irrigation. However, under effluent irrigation, grain yield was enhanced significantly.

Sahai *et al.*, (1985) studied, at Gorakhpur, (Uttar Pradesh), the effect of distillery waste water on the growth behaviour of a leguminous crop (Phaseolus radiatus). The effluent was highly acidic and contained high amounts of Ca, Cl, HCO_3, N and total dissolved solids. Its BOD value was also high. They noted that the respective lengths of the root and shoot, biomass, net primary productivity, seed output and chlorophyll contents were considerably increased when the plants were irrigated with 5% effluent. The distillery effluent as such was highly toxic to the growth of the plant. They also observed that soluble N and protein contents of the seed increased at effluent concentrations upto 50 and 15% respectively.

Singh *et al.*, (1985) studied the effect of sugar mill and distillery effluent on seed germination and seedling growth of three varieties of rice at Muzaffarnagar (Uttar Pradesh). The effluent samples were acidic and contained considerable amount of various pollutants resulting in high BOD and COD. They found that germination was not affected in 10% effluent concentration and thereafter progressive decrease was recorded with increased effluent concentration. The growth of the seedlings was inhibited under various concentrations of the effluent, viz. 25,50,75 and 100%. They suggested that the effluent could be used for irrigation after proper dilution.

Adhikary and Sahu (1986) studied the effect of distillery effluent and the blue green alga *Anabaena* on the growth and development of rice seedlings at Keonjhar (Orissa). They found that diluted effluent of distillery (1-10%) supported the seedling growth of rice. A significant increase in vegetative growth of paddy was noted when 10% neutralised distillery effluent and *Anabaena* were supplemented in different combination.

Sant and Jha (1986) studied the effect of chemical factory effluent at Varanasi (Uttar Pradesh) on germination of finger millet seeds and on seedling growth. Seeds were treated with different concentrations of effluent, viz.2.5, 10, 25, and 100% Results on mortality, seed germination quantitative changes and seedling growth revealed that the best germination and seedling growth occured in 2.5 to 5.0% effluent only, while seedling growth was inhibited at 10% effluent concentrations and above. They also reported that high concentration of NH_4Cl contributed to the toxicity of the effluent . They , however, recommended that the factory effluent could be used safely for irrigational purposes after proper dilution.

Laboratory experiments were conducted to evaluate the impact of various concentrations (2.5, 5, 10, 25 and 50%) of fertiliser factory effluent on certain physio-chemical properties of soil and on germination, growth, photosynthetic pigments, and dry matter production of maize and rice by Singh and Mishra (1986) at Kanpur (Uttar Pradesh). The effluent was highly alkaline and contained high amounts of N, Ca, Na, C1, CO_3,HCO_3 as well as suspended and dissolved solids. They found no significant deviation in the germination percentage in the effluent concentration ranging from 2.5 to 5% for the two crops as compared to control. However, higher concentrations of effluent (10% and above) inhibited germination which became zero when irrigated with 100% (undiluted) effluent. Maize and rice plant grown in soil irrigated with low effluent concentration (2.5 and 5% increased height, leaf area and dry matter production as compared to control plants. Plant height showed a maximum increase of 52% for maize and 16% for rice grown on soil irrigated with 5% effluent Number of seeds per plant and dry mass of seeds per plant improved in soil irrigated with low effluent concentrations (2.5 to 5%) but declined as the concentration of effluent increased to 10% and above. They also estimated carbohydrate and protein content of the rice and maize and reported maximum protein and carbohydrate contents in seeds grown with 2.5 to 5% effluent

At Las Villas (USA) a preliminary study was made by Cepero *et al.* (1987) on some chemical characteristics of the soil in a sugarcane field which was irrigated with waste water discharged from the agro-industrial cooperative. Results indicated that irrigating with such water had not produced great changes in soil properties.

Pathmanabhan *et al.*, (1987) conducted a pot experiment at Bangalore (Karnataka) to study the effect of paper mill effluent on various varieties of groundnut. They found that fresh weight recorded on 10th, 20th and 40th day showed little reduction with effluent irrigation except variety 10-5 which showed a reduction of nearly 40% on 20th and 40th day. The decrease in root weight due to irrigation with effluent was significant in all the varieties except S-196. Leaf area decreased significantly at all stages of growth except on the 40th day. The number of branches per plant did not differ significantly due to irrigation or due to varieties. The number of pods per plant, seed weight per plant and hundred seed weight showed a reduction due to effluent irrigation and revealed varietal differences. The dry weight of leaf and stem at harvest decreased significantly due to irrigation in most of the varieties.

Srivastava and Sahai (1987) carried out extensive work at Gorakhpur (Uttar Pradesh) on the effect of distillery effluent applied in various concentrations (1,2.5,5,10, 25, 50, 75, and 100%) on the behaviour leaf area, biomass, net primary productivity, pigment content, seed output, seed weight, seed density and seed protein content of gram. They found that percentage and speed of germination of seeds were inversely proportional with the increase in effluent concentration and at 100% concentration there was no germination. The seedlings exhibited maximum shoot length at 5% concentration and maximum root length at 2.5% concentration. The values of root and shoot lengths,leaf area, biomass, net primary productivity, pigment content, seed output, seed weight, seed density and seed protein content in pot plants exhibited a gradual increase from the control up to 5% concentration but decreased at higher concentrations.

The impact of polluted municipal waste water on growth yield and quality of wheat (cv. HD-2204) was studied by Veer and Lata (1987) at Meerut (Uttar Pradesh). They found that growth and yield of wheat were promoted by polluted water. Promotion in root growth was of greater extent than that of shoot as increase in root fresh weight (275%) and dry weight (285%) when compared to control, while increase in shoot fresh weight and dry weight was 225% and 253% than control. Tiller number per plant was also promoted, being 205% of control. However, leaf area, number, fresh weight and dry weight were not significantly affected. Seed yield per plant was higher in plants receiving polluted water, being 370% more than control while ear length and grain number were not significantly affected. They also noted that protein N, soluble N, reducing sugar and non-reducing sugar content, on unit dry weight basis, in grains of plants irrigated by polluted water were lower, being 82%, 77%, 76% and 80% than control respectively. The total heavy metal content on unit dry weight basis, in root, shoot, leaf and grain of plants irrigated by polluted water was 195%, 356%, 133% and 175% higher than control.

Agarwal *et al.* (1988) studied the heavy metal pollution of air, soil and plants around a zinc smelter at NEERI, Nagpur (Maharashtra). They noted that the metal fraction of the soil showed large variation from metal to metal and site to site. The value of Fe ranged from 6,940 to 13,150 ppm while zinc accumulation varied from 290 to 1,990 ppm. Mn and Pb content ranged from 200 to 590 and 10 to 345 ppm respectively. They also found maximum and minimum Fe accumulation in leaves of *Triticum* spp. and *Acacia* spp., being 15,890 and 520 ppm respectively. The extent of Cu, Cd, Ni and Cr accumulation was much less in comparison to others. Zinc concentration varied from 120 to 4,860 ppm.

Mukherjee and Sahai (1988) studied at Gorakhpur (Uttar Pradesh) the impact of distillery waste on seedling growth of pigeon-pea (arhar). The various growth parameters showed a progressive increase up to 5% concentrations. The root and shoot ratio was maximum in the plants irrigated with 2.5% concentration. The total seed output and total dry weight increased steadily from control to 5% concentration and then decreased gradually till only a few seeds and a small amount of dry matter was produced in the plants treated with 75% concentration. The effluent was acidic, rich in Ca, Cl, HCO_3, total N, organic pollutants, having a BOD value of 32,000 mg/l and was very toxic when used as such for irrigation.

Neelam and Sahai (1988) studied the effect of fertiliser factory effluent at Gorakhpur (Uttar Pradesh) on seed germination, seedling growth, pigment content and biomass of rice. The values for germination percentage and seed germinations increased corresponding with increase in the effluent concentration up to 5%. Length of radicle and plumule, seedling biomass and pigment content considerably increased when the plants were treated with 5% effluent. In another study conducted in 1989, they studied the effect of distillery effluent on the growth response, nitrogen uptake and nitrogen content of moong. The pots were treated with equal amount of different concentrations (1, 2.5, 5, 10, 15, 30, 50, 75 and 100%) of effluent. They noted that respective lengths of root and shoot, plant biomass and nitrogen uptake were markedly increased when the plants were treated with 10% effluent. However, higher concentrations (30 to 75%) had adverse effect. They also analysed the effluent and noted that it was highly acidic (pH 4.5) and had large amount of Ca, Cl, HCO_3, total dissolved solids and organic pollutants. They however, recommended that effluent may be used for irrigation after proper dilution.

Papadopoulos and Stylianou (1988) conducted field experiment in Nicosia (Cyprus) to assess the long term effects of applying treated municipal effluent by trickle irrigation on soil N fertility, soil salinity and yield of cotton under semi arid conditions. Both treated effluent and borehole water were supplemented with 0, 30, 60 and 90 mg N/l. The N concentration in the effluent was about 30 mg/l. Under the conditions, soil types, climate and borehole water and effluent qualities, effluent was comparatively superior to borehole water, particularly at lower N levels and proved beneficial in increasing the yield. It was concluded that treated municipal effluent containing 30 mg N/l could be used effectively by trickle irrigation as a source of irrigation water and N. With appropriate nitrogen and water management, ecological hazards due to NO_3-N may be minimised and salinity and sodicity may be maintained at acceptable levels for cotton cultivation.

Bahadur and Sharma (1989) studied the effect of combined effluent from three industries on growth characteristics of pea at Bareilly (Uttar Pradesh). They noted that all the growth attributes exhibited an overall decrease in effluent irrigated plants as compared to control (tap water). However, the reduction in number of leaves (19.35%) and leaf area (28.08%) was not significant at late vegetative stage (after 75 d). Maximum decrease in leaf area (31.09%) was observed at early growth stage. However, maximum reduction in root length (22%), number of branches (46.8%) and root dry weight (44.42%) was noted at 75 d. The decrease was maximum in shoot length (34.54%), number of leaves (26.60%), shoot dry weight (37.64%), biomass/plant (38.03%), number of inflorescence/plant (41.61%) and dry weight of seeds (38.88%) after 135 d.

Neilson *et al.* (1989) in Summerland (Canada) carried out an extensive study on tomato, sweet pepper, onion, cucumber, bush bean and melon grown with either well water or effluent. It was noted that yields with effluent irrigation were greater than, or similar to, yields obtained with well water. Effluent irrigation resulted in decreased Zn, and increased P and gave variable results for other nutrients in plant tissues. No major limitations were found for the production of high yields of vegetables irrigated with municipal waste water on the loamy sand soil at the experimental site after four years.

2.3 Water stress

The term stress, when used in biology, has a general connotations rather than a precise definition. It is, therefore, appropriate to apply the term stress in its more general sense as "an over-powering pressure of some adverse force of influence" that tends to inhibit normal systems from functioning.

Water is a crucial factor throughout the life of a plant. It acts as a medium for all chemical reactions in the cells. Therefore, any change, either in quantity or quality, induces a series of growth and developmental deviations, like germination, growth, yield and quality of plants (Hsiao and Bradford, 1983).

Among the physicochemical stresses to which a plant may generally be exposed, water, chemical and nutritional stresses are the most frequent. Of these, water stress is generally the result of a suboptimal soil moisture supply, coupled with a rate of transpiration in excess of the rate of absorption. But, even when a plant is well watered, water stress may develop during the hot part of the day if water absorption by roots fails to keep pace with transpiration (Noggle and Fritz, 1986). One of the important damaging effects of water stress is the increase in the concentration of salts within the cells, which can damage the enzyme systems that control metabolism (Salisbury and Ross, 1988).

Bakhshi *et al.* (1975) studied at Ludhiana (Punjab), the protein content of thirty three triticale and two wheat varieties. They observed that the protein content in the triticales ranged from 11.3 to 14.1% under irrigated conditions and from 11.5 to 13.8% under rainfed conditions. The protein content of six triticale strains, viz. TL 3, TL 7, TL 10, TL 11, TL 13 and TL 25 was 14.1, 13.0, 13.4, 13.4, 13.0 and 13.0% compared to 12.7 and 12.2% given by wheat cv., WL 1002 and Kalyansona respectively under irrigated conditions. Under rainfed conditions, all the varieties of triticale, except TL 34 (11.5%), contained higher protein content than Kalyansona (11.6%). It was noted that the protein content of triticale strains TL 1, TL 2, TL 3, TL 4, TL 7, TL 8, TL 14, TL 26, TL 31 and TL 33 were significantly higher under rainfed conditions compared with Kalyansona under irrigated conditions.

Reddy (1976) studied at Hyderabad (Andhra Pradesh) the effect of various levels of irrigation on wheat by taking field capacity as the quantum of irrigation. He applied six levels of irrigations (1/2, 3/4, 1, 3/2, 2, 3 FC) to two varieties of wheat (Sharbati Sonora, HD-1955) keeping no irrigation as control. He recorded maximum grain yield (53.4 q/ha) with 3/4 FC value, followed by 1 FC value (53.2 q/ha), while maximum straw yield (74.8 q/ha) was with 1 FC, followed by 74.7 q/ha with 3/4 FC. Control yielded only 27.9 and 43.2

q/ha grain and straw respectively.

Varma (1976) studied at Hissar (Haryana), the effect of three soil moisture regimes (i.e. irrigation given at 75, 50 and 25% depletion of available soil moisture from 0 - 30 cm of soil), two nitrogen levels (75 and 150 kg/ha) and their interaction on NPK absorption by wheat under field conditions. The wetter irrigation regimes (i.e. irrigation at 50 and 25% depletion) increased significantly NPK uptake but decreased grain nitrogen. The higher dose of N (150 kg/ha) resulted in an appreciable increase in nitrogen uptake and content in grains. The total grain yield was 31.2, 35.7 and 54.6 q/ha with 75%, 50% and 25% depletion respectively. He also noted that maximum grain yield (66.3 q/ha) was obtained with 150 kgN/ha and 25% depletion.

While working on germination of wheat, in the USA Ashraf and Abu - Shakra (1978) observed that, under low temperature and moisture stress, seeds of the four selected cultivars germinated when their moisture content was approximately 50% on a fresh weight basis. They also noted that total germination was not affected by moisture levels up to 12 atm., but was significantly reduced at 15 and 18 atm. osmotic tensions.

Sionit *et al.* (1980) conducted an experiment at Durham, (N.C., USA) on the impact of repeated water stress on wheat. They applied water stress at 7th leaf, early anthesis and dough stage of growth and found that stress of 0.25 bars at all the three stages reduced seed yield. The reduction was greater when the second stress cycle was also applied. Stress applied during early anthesis produced the smallest and least number of seeds. Similarly, decrease in grain yield of wheat was also noted by Saini and Aspinall (1981) at Adelaide (Australia) and by Davidson (1987) in USA.

Sutton and Dubbelde (1980) studied at Sydney (Australia) the effect of water stress on yield of two cultivars of wheat and one of triticale. Water stress was imposed beofe anthesis, after anthesis, and during the complete life cycle. Under continuous water deficit the cultivar of triticale produced less than the wheat. Similarly, Sinha *et al.* (1986) of IARI (New Delhi) were of the opinion that *T. aestivum* was more resistant than triticale. On the other hand, Mashhady *et al.* (1982) found triticale more tolerant than wheat under water stress in Saudi Arabia. Singh (1982), while working at Muzarffarnagar (Uttar Pradesh), studied the effect of moisture stress on two varieties of wheat and found that UP 319 was more resistant to increasing water stress conditions than HD 1981.

Joshi and Singh (1983) conducted a field experiment at Udaipur (Rajasthan) to study the performance of wheat cv. NP-718, MPO-190, JNK-4W-184, HD-4530, J-40, J-142, HI-601, Sonalika, Kalyansona and Raj-911, under limited irrigation (I_0, I_1 and I_2). They found an increase in grain production owing to one (18.70%) and two irrigation levels (45.53%). Applying one extra irrigation at boot stage over crown root initiation (CRI) gave 22.59% higher yield. Similarly, the impact of water stress on yield parameters of wheat was also studied by Oosterhius and Cartwright (1983) at Pretoria (S. Africa). They observed that moisture stress at late vegetative stage (before the formation of spike) adversely affected the final number of fertile florets per spike. They also noted that water stress caused death of spikelets.

Aggarwal and Sinha (1984) studied at IARI (New Delhi) the effect of water stress on grain growth and assimilate partitioning in two cultivars of wheat (C 306, Kalyansona) contrasting in their yield stability in a drought environment. They noted that leaf area was decreased after 60 and 75 days respectively and rate of decrease was more in C 306 than in Kalyansona. They came to the conclusion that water stress had no effect on absolute amount of pre-anthesis dry matter translocated to the grain in either variety. The absolute post anthesis assimilate contribution to the grain yield was greatly reduced by water stress, especially in Kalyansona.

Yadav and Srivastava (1986) conducted a field experiment at Kanpur (Uttar Pradesh) to study the effect of sowing date, irrigation and fertility level on protein and lysine contents and yields on triticale var. UPT 72142. They noted that one irrigation gave significantly higher protein content over two. "Increased protein yield, lysine content and per hectare lysine yield were obtained by both one and two irrigations. They also noted that increasing fertility levels enhanced grain protein content and per hectare protein and lysine yields while grain lysine was adversely affected.

On the basis of drought susceptibility index(s) and yield potential

(Yp), Aggarwal and Sinha (1987) of IARI, New Delhi showed that varieties of wheat and triticale with low S and other moderate Yp produced more spike/m^2 than the other irrespective of the water status. Varieties with high Yp and low S out-yielded the other varieties in irrigated and moderate drought environments because they had higher values for spike/m^2 and grain/spike, varieties with low Yp and high S had the lowest values for spike/m^2, grain /spike and dry matter production. However Bhardwaj *et al.* (1987) noted that weight of grain present at the basal and middle region of the ear was also reduced when water stress was imposed in two varieties of wheat (Kalyansona and C-306).

Gupta and Patil (1987) carried out extensive field work on triticale at IARI, New Delhi. During 1981-82, they observed that triticale cv UP7740 and UP72142 and wheat cv HD 2204 gave 4.45, 3.99, 3.72 t/ha average grain yield with 5,3 and 2 irrigations respectively at atmopheric tension 0.4, 0.6 and 0.8. During 1982-83 the average yield was 3.84, 3.95 and 3.49 t/ha , respectively. They also noted that 1,000 grain weight was higher with 2 or 3 irrigations than with 5 irrigations in 1982-83 but was not affected by irrigation regimes in 1981-82. They also noted that increasing nitrogen reates from 0-100 kg/ha increased the yield in both the years. However, yield was decreased with 150 kg.N/ha. Wheat cultivar HD 2204 gave yields of 4.39 and 3.79 t/ha in the two years as compared with 3.77 and 4.00 t/ha for UP 7740 and 3.59 and 3.61 t/ha for UP 72142 triticales respectively.

Retardation in leaf area, number of tillers, ear number/m^2 and grains/ ear was also observed in wheat under imposed moisture stress by Hassan *et al.* (1987) of Nigeria, Ivanov *et al.* (1987) of USSR and Kumar *et al.* (1987) of Hisar (Haryana).

Prasad *et al.* (1987) conducted a field experiment on wheat at Pusa (Bihar) with four irrigation levels (IW/CPE) ratio of 0.4, 0.6, 0.8 and 1.0 with 6 cm depth of irrigation water) and five levels of nitrogen (40,60,80,100 and 120 kg/ha). They found maximum grain yield (47.06 q/ha) with four irrigations, i.e. 1.0 IW/CPE ratio and 120 kg N/ha, followed by 43.58 q/ha with four irrigations and 100 N kg/ha. The yield with one irrigation was 20.20 q/ ha with 40 kg N/ha and 28.53 q/ha with 120 kg N/ha. During the same year, Singh *et al.* carried out a field experiment at Sehore (Madhya Pradesh on wheat cv HD-1925 with 150+60+40 kg of NPK and 21 irrigation schedules. Each irrigation treatment was of 75 mm depth. They found maximum grain yield (39.8 q/ha) with six irrigations followed by 36.5, 35.8, 33.7, 29.5 q/ ha with 5 irrigations, while it was 13.0 q/ha only with no irrigation.

Malavia *et al.* (1987) conducted field experiments at Junagadh (Gujarat) with three soil moisture regimes (0.8, 1.0, 1.2 IW/CPE four levels of N 0, 60, 120 and 180 kg/ha and two of P (0,60 kg/ha) on wheat. They found maximum grain yield (33.9 g/ha) with 1.2 IW/CPE ratio followed by 30.1 q/ha with 1.0 IW/CPE while it was 28.0 q/ha with 0.8 IW/CPE. They also observed that 120 kg N/ha and 60 kg P/ha yielded maximum grain (34.3 and 32.3 q/ha respectively).

Chowdhury *et al.* (1987) screened sixty wheat genotypes under six different irrigation levels at Hisar (Haryana) They found that the most tolerant varieties were Narbada 4, K 7404, NP 873, LSW 131 and HS 82. They recommended that varieties N 15439, HP 1258, HS 82, D 134, Narbada 112 and K 7404 were suitable for restricted irrigated environment. While Narang *et al.* (1988) of PAU Ludhiana suggested the application of irrigation at three growth stages (crown root initiation, jointing and boot) in place of the normal four irrigations. They also reported that failure of any irrigation at any of the three growth stages resulted in reduced grain yield, being more severe at crown root initiation and boot stage particularly in late sown wheat varieties.

A field experiment on wheat was conducted by Panda *et al.* (1988) at Sambalpur (Orissa). They applied four irrigation schedules (0.6, 0.8, 1 and 1.2 IW/CPE ratio) and three levels of nitrogen (40, 80 and 120 kg/ha) on wheat cv Sonalika. They found maximum grain and straw yield (23.6 q/ha and 18.9 q/ha respectively) with 5 irrigations i.e. 1.0 IW/CPE ratio. They also observed that grain yield increased with the increase in nitrogen level. The growth and yield parameters increased significantly with increase in IW/CPE ratio of irrigation.

Ghandorah (1989) studied the drought tolerance of twenty two durum wheat varieties in Saudi Arabia. The varieties were grown under three water regimes obtained by irrigating the soil at 80,60 and 40% of the available moisture. They found that increase in the available moisture percentage increased grain yield.

Khola *et al.* (1989) conducted an experiment at Hisar (Haryana) to study the effect of varying levels of irrigation and fertility on moisture use by wheat cv. WH - 291. They applied 5 levels of irrigation at crown root initiation (CRI), jointing (J) maximum tillering (MT) and milky grain stage (M). The grain yield increased significantly with increase in number of irrigations and highest grain yield (38.5 q/ha) was obtained under 1.2 IW/CPE ratio while one irrigation at CRI gave minimum yield (21.1 q/ha). They also noted that increasing the fertility level increased the grain yield and highest grain yield was obtained under 125 kg N/ha.

Nagarajarao and Mallick (1989) grew wheat cv. HD 2160 with irrigation and without irrigation in a field trial at New Delhi. They found that grain yield was severely affected when the crop was not given any irrigation, being 1.32 t/ha only when compared with the yield (5.07 t/ha) obtained with irrigation.

Talukadar *et al.*(1989) of Bangladesh studied yield and water use of field grown wheat as affected by water stress. They noted that water stress at all the growth stages reduced grain yield and water use significantly but the effect was maximum when stress was imposed from booting to flowering stages. They also noted that increase in water use decreased the water use efficiency but increased harvest index.

Khan *et al.* (1990) conducted a field experiment at Morena (Madhya Pradesh) to study the effect of four levels of irrigation and two levels of nitrogen on wheat cv. WH - 147. They observed an increase in grain yield by increasing the number of irrigations. They obtained 61.3 q/ha grain yield with 120 kg N/ha while, with 60 kg N / ha the grain yield was 51.07 q/ha.

Patra (1990) carried out a field experiment to study the yield potential of two wheat varieties (Sagarika and Sonalika) under varied levels of fertiliser and irrigation. They observed that increasing the number of irrigation increased the yield significantly and highest yield was obtained under four irrigations. The maximum (29.5 q./ha) and minimum (23.7 q/ha) yield was obtained with four and two irrigations respectively. They also found that increasing the fertiliser level significantly increased the grain and straw yield.

While working with various crops (barley, maize, pearl millet, rice, sorghum and soybean) under different agroclimatic conditions a general decrease in growth and yield due to environmental stresses was also observed by Singh and Tripathi, 1972; Lewis *et al.*, 1974; Krishnamurthy *et al.*, 1975; Stout *et al.*, 1978; Wilson and Allison, 1978; Cure *et al.*, 1980; Herrero and Johnson, 1981; Kobata and Takami, 1981; Singh *et al.*, 1981; Rahman and Yoshida, 1983; Ravindranath and Shivraj 1983; Mahalaxmi and Bidinger 1986; El-zeiny and Kortam 1987; Rego *et al.*, 1988 and Singandhupe and Rajput, 1989.

2.4 Potassium and water use efficiency

Potassium is the most abundantly distributed cation and is highly mobile but does not appear to be a constituent of the plant body. The function of this element in plant metabolism is biophysical and biochemical, involving ion fluxes as it maintains turgor pressure of the cell via osmo-regulation and activates more than 60 enzymes covering a wide spectrum of plant metabolism (Evans and Sorger, 1966; Nitas and Evans, 1969; Suelter, 1970). It is also involved in the translocation of photosynthates and helps in the synthesis of proteins (Webster, 1956; McKee, 1962) and ATP (Beringer, 1982). These physiological roles, coupled with removal of large quantities of potassium by crops, necessitating its replenishment after every harvest, account for its increasing demand in ensuring desired crop productivity (Beringer, 1982). K^+ ions are known to be involved in stomatal opening and closing which is important for gas exchange and is severely influenced by water deficit, salt and pathological stress. Potassium not only facilitates water uptake but also prevents excessive water loss. Therefore, water use efficiency increases in its presence. The performance of crops under drought conditions is, therefore, improved through tolerance and/or avoidance of drought brought about by potassium nutrition. (Brag, 1972; Mengel, 1977 Beringer and Trolldenier 1978; Lauchli and Pfluger, 1978; Mengel and Kirkby, 1980).

Rajagopal *et.al.* (1971) studied the diurnal fluctuation in proline content RWC and NR in the flag leaf of *Triticum vulgare,* cv. Kalyansona grown under stressed and non-stressed conditions. They observed that the accumulation of proline in stressed plants was ten-fold compared to non-stressed plants. They also found that,with the decrease in relative humidity and RWC, the amount of proline got enhanced more than twice in stressed plants. The proline content dropped to nearly 2 mg/g of leaf once RWC was restored to 72.5%, while there was increase in proline accumulation in non-stressed plants in the night.

Blum and Ebercon (1976) of Israel studied the accumulation of proline on sorghum and found that during moisture stress there was increase in the proline content, but on rewatering, there was a general decrease in proline content.

Singh and Singh (1982) conducted studies at Muzaffarnagar (Uttar Pradesh) on two cultivars of wheat i.e. HD 1981 (drought resistant and UP 319 (drought sensitive). Seeds were germinated in distilled water then transferred to various stresses created by PEG resulted in considerable rise in proline accumulation in both the varieties. The relative proline accumulation increased with increasing stress levels. The accumulation of free proline was more in HD 1981 at various stress levels and periods than in UP 319.

Sairam and Dube (1984) found at Almora (Uttar Pradesh) that wheat accumulated high amounts of proline when there was moisture stress and there were varietal differences in the extent of proline accumulation.

Varieties that accumulated more proline under moisture stress showed symptoms of wilting at much lower soil moisture regimes than those which accumulated less proline.

Patel and Vora (1985) studied proline accumulation at Ahmadabad (Gujarat) in wheat, *Plantago, Papaver* and mustard. Plants were grown in the field with low to high water content and were subjected to water stress. They found that water stress enhanced the proline content in all crops studied.

Yadav *et al.* (1987) studied at Kanpur (Uttar Pradesh) the relative water content and proline accumulation in relation to drought tolerance in wheat. They observed higher proline content in K - 7229 and K-8027 under stress conditions. They also found that leaves accumulated more proline.

Nakashgir *et al.* (1988) studied the effect of potassium and farm yard manure at Sopore (Jammu and Kashmir) on yield and water use by maize and wheat under rainfed conditions. In wheat cv. WL 711 an increase in grain and straw yield from 3.45 to 4.21 t/ha without farmyard manure and from 3.87 to 4.61 with farmyard manure was recorded. Potassium application had no effect on water use efficiency of wheat.

Narayan and Mishra (1989) studied free proline accumulation and water stress resistance in various varieties of bread wheat *(T. aestivum)* and durum wheat *(T. durum)* at Pantnagar (Uttar Pradesh). They observed that all varieties had higher proline level under non-irrigated conditions. Varieties WL 2265, IWP 72, UP 115, DWL 502 and Raj 1865 that had the highest proline content gave highest yields and had high yield stability indices.

While working with cotton, cucumber, groundnut maize, mulberry, mustard, rice, sorghum and soybean, a general increase in proline was found with increasing levels of potassium and induced drought (Mukherji, 1974; UdayKumar *et. al.,* 1971; Janagoudar *et al.*, 1983; Singh and Gupta, 1983; Biswas and Chaudhury, 1984; Fukutoko and Yamada, 1984; Jorge *et al.*, 1988; Sivaramarkrishnan *et al.,* 1988; Veeranjaneyulu and Kumari 1989; Khan. 1991; Umar *et al.,* 1991).

2.5 Triticale, its history and progress

As pointed out earlier p. , triticale is an artificial derivative of a cross between wheat and rye. Its history is just about a century old with Wilson in 1975, publishing the first report of a hybrid between wheat and rye. He obtained two seeds by hand pollinating emasculated wheat florets with rye pollen. But there was a serious disadvantage because of seed sterility and a further generation could not be obtained. In 1983, Carman made another cross between wheat and rye. A single hybrid plant was open pollinated and a descendant variety, RNY No. 6, was later grown to some extent. However it was the German scientist Rimpau who succeeded in producing a fertile hybrid of wheat and rye in 1891. In the beginning of the twentieth century, Strampelli crossed Rieti wheat with rye and back crossed the F1 with

Rieti. In 1915, natural occuring wheat x rye hybrids were described by Leighty which were found in wheat fields and in experimental plots of wheat at the U.S. Department of Agriculture Experimental Farm. Intensive research on triticale, however, was started at Sartov Reseach Station (USSR) in 1918. The wheat-rye natural hybrid Erythrospermum 46/31, in South Eastern Russia, represented a major contribution to the USSR economy in later years. In 1928, Meister and Tjumjakoff produced reciprocal wheat rye hybrids. In these crosses, seed set was comparatively higher using the wheat parent as female (Briggle, 1969).

Arne Muntzing began intensive research on triticale in 1934 at the University of Lund (Sweden), that still continues. His contribution to the knowledge of the cytology, genetics and improvement of triticale is outstanding. His work did much to encourage other scientists to undertake triticale research in many parts of the world. The use of colchicine, by Pierre Givanden (1937), in France, to overcome the disadvantage of sterility and of embryo culture techniques perfected in 1940, proved of great advantage in this respect. The first hexaploid triticale was reported by Derzhavin (1938) from a cross between durum wheat and *Secale montanum*. A hexaploid triticale from a durum wheat x cultivated rye *(S. cereale)* cross undertaken by O; Mara (1948), played an important role in the development of triticale in North America and Europe. Soon, numerous new hexaploid triticales were produced from combinations of different tetraploid wheats and diploid ryes at various research centers by Nakajima, 1952, 1958, 1963; Sanchez - Monge *et.al.* 1956, 1959; Pissarev, 1963; Kiss, 1966; Larter, 1968 and Jenkins, 1969 (Zillinsky, 1974).

Discoveries of new techniques in plant breeding opened the door for further promotion of triticale. Significant contribution was made by Kiss, a Hungarian plant breeder who started research on triticale in 1949. He took *Triticum turgidum* as female parent in crosses with Hungarian rye varieties and obtained his first primary hexaploid triticale in 1951. In 1952, he also produced a primary octaploid triticale. He started crossing octaploid and hexaploid triticales in 1954 and obtained in 1960 a secondary hexaploid triticale that was more productive than either of the parental forms (Zillinsky, 1974).

At the University of Manitoba research on triticale was started by Borlaug in 1958. Later, in 1964, CIMMYT (Mexico) joined a cooperative research programme to accelerate the development of triticale as a cereal crop. This research project on triticale was finally assisted by Rockefeller Foundation, the Ford Foundation and the US Agency for International Development (Mackenzie *et al.* (1973).

In 1968, intensive selection trials were conducted to obtain better fertility in triticales. Finally a few plants with improved fertility were found in the F_4 population of a cross between two hexaploid triticales. The average percentage of seed set of two of the original lines was about 6% below that of adapted bread wheat strains and 15% above the best original hexaploid triticale. These few plants eventually provided a major breakthrough in triticale improvement. among the characters associated with these selections, which were later identified as Armadillo strains (Zillinsky and Borlaug, 1971), were high fertility, improved test weight, better grain yield, insensitivity to day length, one gene for dwarfness, early maturity and good nutritional quality. A verification that a bread wheat progenitor was involved in the origin of Armadillo was obtained in 1973 when a D chromosome was found tobe substituted for one of the rye chromosomes (Gregory, 1973).

As the weather pattern at CIMMYT's Toluca experiment station in Mexico allows winter gowth habit cereals to be planted in November, crosses like winter triticale, winter rye x spring wheat, winter wheat x spring rye and winter rye x spring triticale could be undertaken in the field on a large scale. When the first test of winter triticale was conducted at Ontario (Canada) in the winter of 1974-75, 90% of the planting was killed by cold and most of the survivors were very poor types. But, of the surviving triticales, one plant in ten looked as good as spring triticale grown in Mexico and these formed the parent stock for continuing improvement (Anonymous, 1976 a).

International testing data continued to confirm the high yield potential of triticale and production advantage over wheat mostly in problem areas such as acidic soils, drylands, highlands, winter regions, high production winter regions, mediterranean regions, sub-continent regions and cool highland production environment (Anonymous, 1980; Abdalla *et al.* 1989).

Together with progress in the areas of genetic and breeding human and animal nutrition, disease and pest resistance, baking quality, agronomical practices, weed and weed control, entomological studies, agricultural economics and physiology of triticale, studies on mineral nutrition and fertiliser application were also undertaken at various places, both outside India (Prohaszka *et al.*, 1971; Lafever and Schmidt, 1972; Sanchez-Monge, 1972; Acosta, 1973; Kiss, 1973; Fodor, 1974, Nass *et al.*, 1975; Anonymous, 1976, b; Andrascik and Licko, 1977; Etchevers and Moraghan, 1978; Pino and Rodriguez, 1980; Ponce *et al.*, 1981; Jardine and Gunther, 1982; Graham *et al.* 1983; Barriga *et al.*, 1984 a, b; Dimitrov, 1984, 1985; Baier and Liuz, 1985; Saleh *et al.*, 1985; Latif *et al.*, 1986; Tasaukova *et al.*, 1986; Aquilina, 1987; Naylor, 1987; Vaulina, 1987; Bizid *et al.*, 1988; Gohil, *et al.*, 1988; Peterson and Allan, 1989; Gardner and Barnett, 1990; Hassawi *et al.*, 1990; Bàier, 1991) in India (Sisodia, 1971; Anand, 1972; Chauhan 1972; Chauhan and Bajpai, 1972; Chandrappa, 1973 ,74; Reddy and Lal 1976; Agarwal, 1977, 1979; Dhiman and Kalra, 1977, 1978; Misra, 1977; Ali and Rajput, 1978; Bhardwaj and Agarwal, 1978; Gill *et al.* , 1981, 1986, Modi and Lal, 1981; Chawla and Kapoor 1982; 1983; Singh *et. al.*, 1982; Sinha *et al.* 1986; Samra and Singh 1987, Aggarwal and Sinha 1987; Kaur *et al.*, 1988; Malik *et al.* 1988; Reddy, 1989; Reddy and Bahl, 1989), including the intensive research undertaken at Aligarh (Afridi *et al.*, 1977; Inam, 1978; Abbas, 1980; Inam *et al.,* 1982 a,b; Abbas *et.al.* , 1983 a,b; Ashfaq *et al.,* 1983; Alvi, 1984, Alvi *et al.*, 1984; Ashfaq *et al.*, 1984; Inam *et al.*, 1985; Moinuddin and Ata, 1985; Moinuddin *et al.*, 1985; Ashfaq 1986; Abbas and Kumar, 1987; Haque *et al.*, 1988; Haque, 1989; a, b; Moinuddin *et al.*, 1990 a, b; Samiullah, 1991). To conclude it is evident from the above review of literature that (i) waste water application has great potential if it is applied at proper concentration and with care and (ii) triticale, being a promising crop capable of adapting well to conditions generallly considered adverse for crop plants, could be tested to determine the suitability of its production on large scale when irrigated with treated refinery waste water.

CHAPTER 3

MATERIALS AND METHODS

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CHAPTER 3

MATERIALS AND METHODS

To fulfill the aims and objectives mentioned earlier (Chapter 1) four experiments were conducted at farm adjacent to Mathura Refinery, Mathura (Fig-3) on three varieties of triticale and one of local wheat as check.

3.1 Agroclimatic conditions of Mathura

Mathura Refinery is located on National Highway No.2 about 10 km away from Mathura City towards Agra at an altitude 27°-22' and longitude 77°-40' E with an elevation of 174 m above MSL (Fig. 2.) The entire area has been reported as having semiarid climate with atmospheric temperature ranging from 22-42°C (maximum) and 7-30°C (minimum), relative humidity 25-95%, light intensity 0.7-5.6 Oktas (cloudiness) and rainfall 908.7 mm per year. The soil is poor being sandy loam. It has high exchangeable sodium percentage and moderate water retaining capacity. The ground water is comparatively saline and brackish and the water potential in the region is very high with water table just 2-3 m deep from the surface.

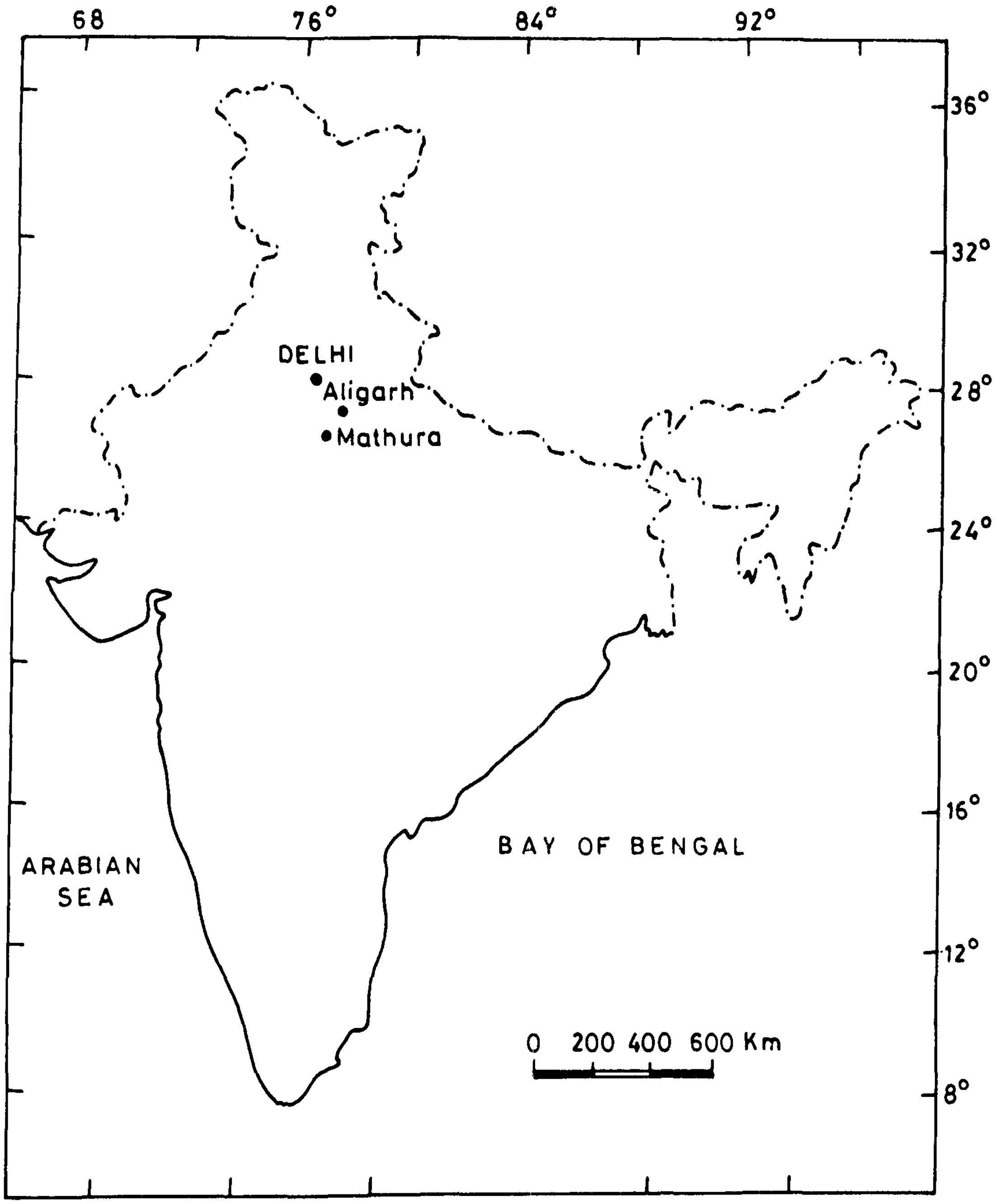

FIG. 2 THE MAP OF INDIA SHOWING THE LOCATION OF MATHURA AND ALIGARH

3.2 Preparation of experimental field

Before the start of each experiment, the field was thoroughly ploughed to ensure proper aeration. Sufficient quantity of farm yard manure was added to maintain proper fertility and water holding capacity of the soil. Plot size was kept 10 sq.m. One light irrigation was given before each sowing to provide proper moisture for maximum germination.

3.3 Field experiments

The following four field experiments were conducted at the Experimental Farm of Mathura Refinery, Indian Oil Corporation, Mathura (U.P.), India (Figs 3-8).

3.3.1 Experiment 1

This experiment was conducted during the rabi season of 1988-89 to study the impact of refinery waste water irrigation on the comparative performance of three varieties of hexaploid triticale. In addition ground water and one variety of locally popular wheat were also taken as checks. The triticale varieties Delfin and Driera were obtained from CIMMYT, Mexico and TL-419, from Punjab Agricultural University, Ludhiana (Punjab). The wheat variety HD-2204 was obtained from Government Agricultural Farm, Mathura. In a split plot design with three replicates, there were two main plots consisting of treated effluent discharged from Mathura Refinery,

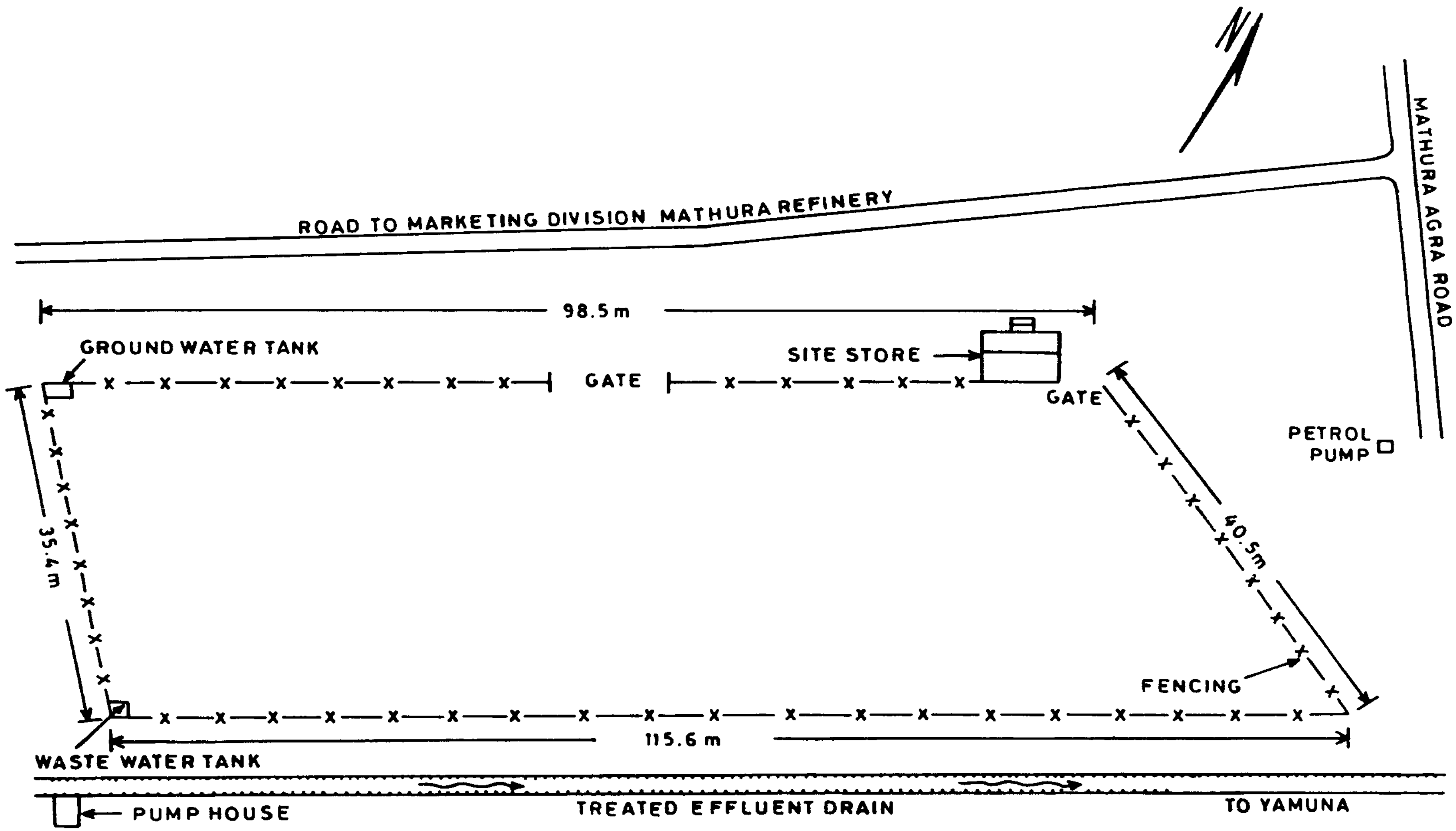

FIG. 3 EXPERIMENTAL FARM AT MATHURA REFINERY

Fig 4. Research station at Mathura Refinery (outside view).

Fig. 5. Research field at Mathura Refinery (inside view).


मथुरा रिफाइनरी
MATHURA REFINERY.
EXPERIMENTAL FARM
IRRIGATION PROJECT
TREATED REFINERY EFFLUENT


TREATED EFFLUENTS
GROUND WATER
भू - जल

Fig. 6. Drain carrying treated effluent towards Yamuna river.

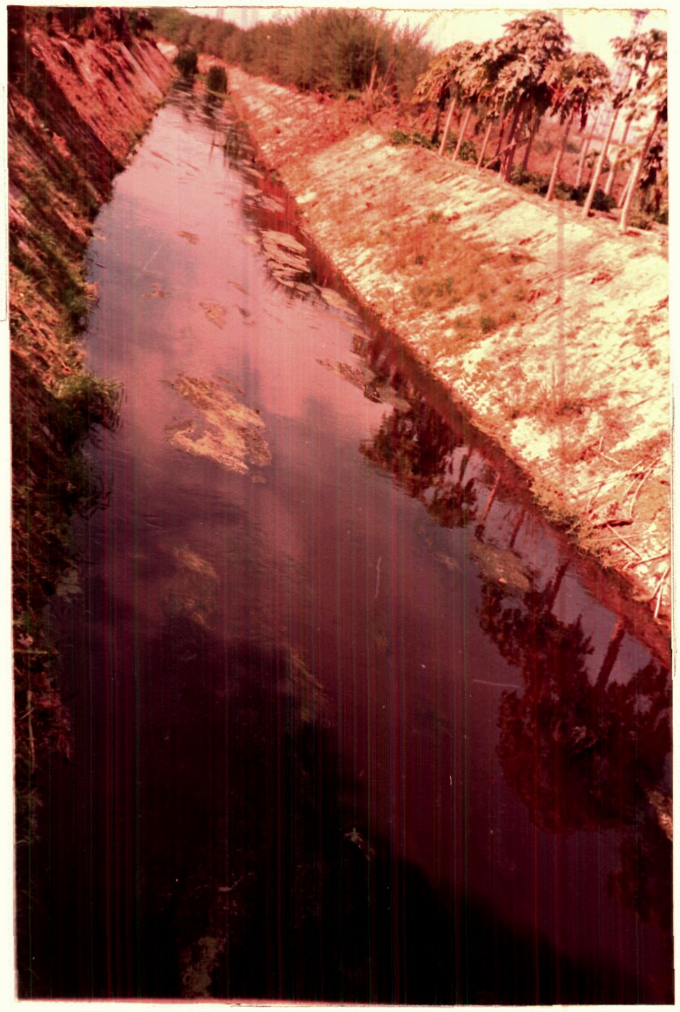

Fig. 7. Pump house for supplying treated effluent to research field.

Fig. 8. Another view of the pump house showing
storage tank of treated effluent.

Mathura and ground water. Sub-plots included four varieties of triticale and wheat. Urea (120 kg N/ha), superphosphate (60 kg P/ha) and muriate of potash (60 kgK/ha) were applied, before sowing, as the sources of nitrogen, phosphorus and potassium respectively (Table 1) in accordance with the findings of Inam (1978) 1000 seeds per bed (approximately 50 kg/ha) were sown on 10th November, 1988, by dibbling (one by one) method to study the germination percentage. Weeding was done at tillering and heading stages of growth. Four irrigations were given at 30, 60, 90 and 120 DAS . The crop was harvested on April 15, 1989. Each plot was irrigated with 1,000 l of water at each irrigation, calculated in accordance with the size of the plot and local requirement A 90° V-notch weir box (Fig.9) was used for measuring the flow using the following formula.

$$Q = 1417\ H^{2.5}$$

Where Q = discharge l/s, and H = height of water over the apex of the notch in cm.

3.3.2 Experiment 2

This experiment was conducted during the following rabi season (1989-90) to study the effect of number of irrigations with treated effluent and the response of one variety of triticale, namely Delfin that performed best in Experiment I grown with a uniform basal dose of fertiliser ($N_{120}P_{60}K_{60}$). In this experience also ground water was taken as check to compare the two

Table 1. Scheme of treatments (Experiment 1)

Sub-plots (Varieties)	Main plots: Treated effluent	Main plots: Ground water
<u>Triticale</u>		
Delfin	+	+
TL-419	+	+
Driera	+	+
<u>Wheat</u>		
HD-2204	+	+

N.B. 1. A Uniform basal fertiliser dose ($N_{120}P_{60}K_{60}$) was given at the time of sowing.

2. Uniform four irrigations were given at 30,60,90 and 120 DAS.

Fig. 9. Weir box showing 90° V notch and mode of irrigation.

types of irrigants. The design of the experiment was split plot with three replicates (Table 2). Here, main plots were based again on two types of irrigation water i.e. treated effluent and ground water. Sub-plot treatments included water stress control (I_0), one irrigation at 30 DAS (I_1), two irrigations at 30 and 60 DAS (I_2), three irrigations at 30,60 and 90 DAS (I_3) and four irrigations at 30,60,90 and 120 DAS (I_4). Sources of NPK, date of sowing, basal doses of NPK were same as in Experiment 1. The seed rate was 125 kg/ha and sowing was done manually by the "behind the plough" method. Rows were kept 20 cm apart. Weeding was done when required Each plot was irrigated with 1,000 l irrigant to maintain uniformity. Harvesting of the crop was done on 17th, April, 1990.

3.3.3 Experiment 3

This experiment was conducted during the third rabi season (1990-91). The aim of this experiment was to study the effect of four levels of treated effluent irrigation and three of basally applied potassium on the performance of one variety of triticale (Delfin). The design of the experiment was split plot with three replicates (Tables 3). Here, main plot consisted of three levels of potassium i.e. K_0,K_{30} and K_{60} while sub-plot consisted of water stress control (I_0), one irrigation at 30 DAS (I_1), two irrigations at 30 and 60 DAS (I_2) and three irrigations at 30, 60 and 90 DAS (I_3). Four irrigations were excluded as they had proved inferior and wasteful in Experiment 2.

Table 2. Scheme of treatments (Experiment 2)

Sub-plots (Levels of Irrigation)	Main plots: Treated effluent	Main plots: Ground water	Remarks
I_0	-	-	Water stress (Control)
I_1	+	+	One irrigation at 30 DAS
I_2	++	++	Two irrigations at 30 and 60 DAS
I_3	+++	+++	Three irrigations at 30,60 and 90 DAS
I_4	++++	++++	Four irrigations at 30,60,90 and 120 DAS

N.B. 1) A uniform basal fertiliser dose $N_{120}P_{60}K_{60}$ was given at time of sowing.
2) The variety of triticale was Delfin.

Table 3. Scheme of treatments (Experiment 3)

Sub-plots (Levels of irrigation)	Main plots (Treatments kgK/ha)			Remarks
	0	30	60	
I_0	-	-	-	No irrigation (water stress)
I_1	+	+	+	One irrigation at 30 DAS
I_2	+	+	+	Two irrigations at 30 & 60 DAS
I_3	+	+	+	Three irrigations at 30, 60 & 90 DAS

N.B. 1. A uniform basal dose of N_{120} and P_{60} was given at the time of sowing.
2. Only treated effluent was used for irrigation.
3. The variety of the triticale was Delfin.

Source of NPK and basal doses of N and P were kept same as in Experiment II. Seed rate was 125 kg per hectare and sowing was done manually on November 9, 1990 by the 'behind the plough' method. Weeding was done when required. The method of irrigation was also same as in earlier experiments. The crop was harvested on 13th of April 1991.

3.3.4 Experiment 4

This experiment was conducted simultaneously with the third experiment (1990-91) to study the effect of refinery effluent on the comparative performance of triticale and wheat under nutrition stress ($N_0P_0K_0$) and varying levels of NPK. The design of the experiment was split plot with three replications (Table 4). The triticale and wheat were the main plot treatments and the fertiliser doses were the sub-plots. The treatments were:no fertiliser (stress), $N_{60}P_{30}K_{30}N_{90}P_{45}$ K_{45} and N_{120} $P_{60}K_{60}$ applied at the time of sowing. Sowing was done manually on November 11, 1990 by "behind the plough" method. Seed rate was 125 kg/ha. Weeding was done twice at tillering and heading stages. The source of irrigant and its mode of application was same as in earlier experiments. Three irrigations at 30, 60 and 90 DAS were given uniformly.

3.4 Sampling

The samples of the soil were collected before sowing and after

Table 4. Scheme of treatments (Experiment 4)

Sub-plots (Fertiliser doses)	Main plots		Remarks
	Triticale	Wheat	
$N_0 P_0 K_0$	-	-	Nutrition stress (control)
$N_{60} P_{30} K_{30}$	+	+	1/2 optimum dose
$N_{90} P_{45} K_{45}$	+	+	3/4 optimum dose
$N_{120} P_{60} K_{60}$	+	+	Full optimum dose

N.B. 1. Uniform three irrigations were given at 30, 60, and 90 days after sowing.
2. Only treated effluent was used for irrigation.

harvesting the crop in each experiment while the samples of water were collected before each irrigation in all the experiments. The samples of plant material were collected at tillering, heading and milky grain stages and finally at harvest.

3.4.1 Sampling of soil

To obtain a composite sample, small quantity of soil was collected from a depth of 15 cm from ten well distributed spots. These were thoroughly mixed on a polythene sheet . Only 500 g of each composite sample was retained for analysis. It was kept in a polythene bag with description and identification.

3.4.2 Sampling of irrigant

Freshly treated effluent (waste water) from refinery and ground water were collected before each irrigation in 5 l plastic containers. To minimise the chance of change (especially for BOD) these were stored at low temperature (4°)C and analysis was done with in 24 h of sampling.

3.4.3 Sampling of plant material

Random sampling of three plants from each plot was done at three growth stages and once at harvest to evaluate the growth, yield and quality characteristics of the crop.

3.5 Germination

In Experiment 1, since sowing was done by "dibbling method", percent germination was also noted to study the effect of treated effluent. Percentage germination was calculated by counting 20 days old seedlings in each plot.

3.6 Growth characteristics

The following growth characteristics were observed at tillering, heading and milky grain stages.

1. Shoot length/plant (cm)
2. Leaf number/plant
3. Tiller number/plant
4. Fresh weight/plant (g)
5. Dry weight/plant (g)
6. Net assimilation rate (Experiment 1 only)

Whereas leaf number is a measure of differentiation and tiller number of meristematic activity, fresh weight and dry weight would account for total productivity in terms of rate of increase of weight, volume and dry matter accumulation.

3.6.1 Net assimilation rate (NAR)

The net assimilation rate is defined as the increase in weight per unit time per unit leaf area present. It was calculated according to the following formula given by Milthorpe and Moorby (1979).

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{2.303 (\log_{10} L_2 - \log_{10} - L_1}{L_2 - L_1}$$

W_1 = dry weight of plant at I growth stage

W_2 = dry weight of plant at II growth stage

L_1 = leaf area of plant at I growth stage

L_2 = Leaf area of plant at II growth stage

t_1 = days of sampling at I growth stage

t_2 = days of sampling at II growth stage

$\log_{10}$ = logarithm to base 10

This would reflect photosynthetic efficiency, rate of differentiation and accumulation of metabolic products in plants.

3.6.2 Relative water content (RWC)

Relative water content was determined by the method of Barras and Weatherly (1962). Turgid weight was measured by soaking leaf discs in covered petridishes containing distilled water for 6 h and calculated by using the following formula :

$$RWC = \frac{W_f - W_d}{W_t - W_d} \times 100$$

Where

W_f = fresh weight

W_d = oven dried weight

W_t = fully turgid weight

Dew was removed before sampling with filter paper and a sharp cutter was used to minimise errors arising from infiltration and injection of water.

3.7 Yield characteristics

The following yield characteristics were observed at harvest.

1) Ear number/plant
2) Ear weight/plant (g)
3) Length/ear (cm)
4) Spikelet number /ear
5) Grain number/ear
6) 1,000 grain weight (g)

7) Grain yield (q/ha)

8) Straw yield (q/ha)

After harvest, the produce was allowed to dry for a few days and the weight of the total produce (straw + grain) of each plot was recorded. The grain from each plot was threshed out manually and its weight was recorded. Straw yield wa obtained by subtracting the grain yield from weight of the total produce recorded before threshing.

3.8 Chemical analysis

The soil, irrigation water and plant parts were analysed for various physio-chemical characteristics as detailed below.

3.8.1 Chemical analysis of soil

The following characteristics were studied in the composite soil sample.

1. Texture
2. pH
3. Organic carbon(%)
4. Electrical conductivity (EC)
5. Phosphorus (kg/ha)
6. Potassium (mg/l)
7. Nitrogen (kg/ha)
8. Sodium (mg/l)

9. Calcium (mg/l)
10. Magnesium (mg/l)
11. Cation exchange capacity (meq/100 g soil)
12. Sulphate (mg/l)
13. Chloride (mg/l)
14. Bicarbonate (mg/l)
15. Carbonate (mg/l)
16. Total dissolved solids (mg/l)
17. Sodium adsorption ratio (SAR)
18. Heavy metal content

3.8.1.1 Preparation of the soil sample in the laboratory

In the laboratory the soil sample was spread on the sheet of paper to break any large lumps with a wooden pestle. Then it was passed through a 2 mm sieve. This sample was used for the study of various physico-chemical characteristics of the soil (Table 5)

3.8.1.2 Soil texture

Texture refers to the relative proportion of sand, silt and clay and specifically soil particles of less than 2 mm in diameter. It is an important soil property because it is closely related to the rate of water intake, water supplying power, the fertility, erosion, aeration and energy

Table 5. Soil characteristics before sowing. All determinations in mg/l in 1:5 (soil : water extract) or as specified.

Determinations	Nov. 1988	Nov. 1989	Nov. 1990	
	Exp. 1	Exp. 2	Exp. 3	Exp. 4
Texture	----------------Sandy Loam ----------------------			
pH[a]	8.1	8.2	8.3	8.3
Organic carbon	1.15	1.32	1.26	1.42
Electrical conductivity[a]*	465	472	468	470
Phosphorus (kg/ha)	12.35	11.45	11.98	12.62
Potassium	8	7	7	8
Nitrogen(kg/ha)	123	125	124	127
Sodium	30	32	38	40
Calcium	27.6	26.0	33.8	30.6
Magnesium	15.23	13.67	16.01	14.65
CEC(meq/100g soil)	2.7	2.6	2.3	2.4
Sulphate	15.11	14.96	14.69	14.32
Chloride	162	164	172	166
Bicarbonate	252	254	262	222
Carbonate	-	-	-	-
TDS	960	980	1080	1020
SAR[b]	1.86	2.10	2.13	1.82

a - 1:2 (Soil : Water (W/V) extract)

b - Saturation extract

* - μ mhos/cm.

required to till the soil.

It was determined by a rapid procedure by rubbing the soil between the thumb and the index finger. For this, a small quantity of the dry soil was moistened and mixed thoroughly in a glass dish to form a soft ball and then worked until stiff and squeezed out between the thumb and forefinger.

3.8.1.3 Estimation of pH

An important chemical property of the soil as medium for plant growth is its pH value. Because, the essential ions that enter the plant nutrition are highly dependent upon the hydrogen ion concentration of the soil solution.

It was observed with the help of pH meter. To 20 g of soil, 40 ml of distilled water was added and shaken thoroughly. After 30 min, pH of the suspension was observed. Before reading, pH meter was calibrated with a standard buffer of known pH (Jackson, 1973).

3.8.1.4 Estimation of total organic carbon

It was estimated according to the method given by Walkley and Black (1934). 2 g of soil was taken in a 500 ml conical flask. To this, 10 ml of 1N potassium dichromate (Appendix p V) solution and 20 ml of concentrated sulphuric acid were added. After shaking for about 2 min, it was kept on an asbestos mat for about 30 min. Then 200 ml of distilled water, 10 ml of Ortho-phosphoric acid (85%) and 1 ml of diphenyl amin indicator (Appendix p V) were added. A deep violet colour was developed, which was titrated against N/2 ferrous ammonium sulphate solution (Appendix p V) till the colour changed to purple and finally green. Simultaneously, a blank was also run. Percentage of organic carbon was calculated as follows :

$$\text{Percent of organic carbon} = \frac{\text{Blank titre} \times \text{Actual titre}}{\text{Weight of dry soil in g}} \times 0.003 \times 100 \times N$$

Where N is the normality of ferrous ammonium sulphate solution.

3.8.1.5 Measurement of electrical conductivity (EC)

It is a numerical expression of the ability of sample to carry electric current which depends on the total concentration of the ionised substances disolved and the temperature at which the measurement is made. 10 g of soil was shaken intermittently with 40 ml of distilled water in 150 ml conical flask for 1 h and then allowed to stand. The conductivity of the supernatant liquid was determined with the help of HACH model DR-EL/4 conductivity meter. The apparatus was adjusted to a known temperature (25°C) of the solution (Jackson, 1973).

3.8.1.6 Estimation of available phosphorus

To the 2.5 g of soil in 100 ml conical flask a pinch of Draco G-60 was added followed by 50 ml of Olsen's reagent (Appendix p.V). A blank was also run. The flasks were filtered through Whatman No. 1. filter paper. In the filtrate, phosphorus was estimated colorimetrically using the method of Dickman and Brays (1940).

5 ml of soil extract was pipetted into 25 ml volumetric flask and 5 ml of Dickman and Bray's reagent (Appendix p VI) was poured drop by drop with constant shaking till the effervescence due to CO_2 evolution ceased. The inner wall of the nek of the flask was washed with distilled water and the contents diluted to about 22 ml. Then, 1 ml of stannous chloride solution (Appendix p VI) was added and volume made upto the mark. The intensity of blue colour was read at 660 nm on a " Spectronic 20" colorimeter.

0.439 g of potassium dihydrogen orthophosphate (KH_2PO_4) was dissolved in about half a litre distilled water. To this 25 ml of 7N H_2SO_4 (Appendix p VI) was added and volume as made upto 1 litre with distilled water, giving 100 ppm stock solution of P (100 µg P per ml). From this, 2 ppm P solution was made after 50 times dilution. For the preparation of the standard curve, different concentrations of P (1,2,3,4,5, and 10 ml of 2 ppm P solution) were taken in 25 ml volumetric flasks. To these, 5 ml of extracting reagent (Olsens reagent) was added. The colour was developed by adding Dickman and Bray's reagent and stannous chloride and read at 660 nm. The curve was plotted by putting the colorimeter reading on the vertical axis and the amount of P (in ug) on the horizontal one.

3.8.1.7 Estimation of potassium

5 g of soil was shaken with 25 ml of neutral (pH 7) normal ammonium acetate (Appendix p VI) for 5 min. and was filtered immediately through a dry Whatman No.1 filter paper. Potassium concentration in the extract was determined flame photometrically.

Stock solution of 1000 ppm K was prepared by dissolving 1.908 g KCl in 1 l of distilled water. From the stock solution aliquots were diluted in 50 ml volumetric flask with ammonium acetate solution to give 10 to 40 ppm of K. These were read with the help of a flame photometer after setting zero for the blank and at 100 for 40 ppm of K. The curve was obtained by plotting the readings against the different concentrations (10,15,20,25, 30, 40 ppm) of K.

3.8.1.8 Estimation of nitrate nitrogen

Nitrogen was estimated by the method of Ghosh *et.al.* (1983). 20 g of soil was shaken continuously with 50 ml distilled water for 1 h in 100 ml conical flask fitted with a rubber stopper. A pinch of $CaSO_4$ was added and the flask again shaken for a few minutes. The contents were then filtered through a filter paper (Whatman No.1). 20 ml of the filtrate was transferred to a 50 ml porcelain dish. It was evaporated to dryness on a water bath. After cooling, 3 ml of phenol disulphonic reagent (Appendix p VII) was added, followed by the addition of 15 ml of distilled water and stirring with a glass rod. On cooling, the contents were washed down into a 100 ml volumetric flask. Ammonia (1:1) was added slowly with mixing till the solution was alkaline which was indicated by the development of yellow colour due to the presence of nitrate. Then, another 2 ml ammonia was added and the volume was made upto 100 ml with distilled water. The intensity of yellow colour was read in a photo-electric colorimeter, using a 420 nm (blue) filter.

For the preparation of standard curve, a stock solution containing 100 ppm nitrate nitrogen (NO_3-N) was prepared by dissolving 0.7215 g of potassium nitrate in distilled water and the volume was made upto 1 l. This was diluted to give a10 ppm NO_3-N solution. Aliquots (2,5,10,15,20 and 25 ml) were evaporated on waterbath to dryness in porcelain dishes. After cooling, 3 ml of phenol disulphonic acid was added and yellow colour was developed which was read as described above. A blank was also run and a calibration curve was drawn between concentration of NO_3-N and colorimeter reading.

Calculation:

NO_3-N (kg/ha) =

$$\mu g \text{ of } NO_3\text{-N in test solution} \times \frac{50}{20} \times \frac{1}{20} \times \frac{2.24 \times 10^6}{10^6}$$

$$= \mu g \text{ of } NO_3 \text{ - N in test solution} \times 0.28$$

3.8.1.9 Estimation of sodium

The ratio of sodium to total cations is important in agriculture. Soil permeability has been harmed by a high sodium ratio. The determination of sodium was carriedout directly with the soil extract (1:5) with the help of flame photometer, using appropriate filter and standard curves prepared by taking known concentration of sodium.

5.845 g of NaCl was dissolved in distilled water and the volume was made upto 1l which gave 100 milli equivalents per litre of Na. From this stock solution, dilutions containing 5,10, 20, 30, 40, and 50 meq. Na/l were prepared. The curve was drawn by plotting the flame photometer readings on the vertical axis against concentration of the Na in the unknown sample was read from the curve.

3.8.1.10 Preparation of extract for Ca and Mg

100 g soil was transferred to a 750 ml flask. To this 500 ml distilled

water was added and the flask shaken for about 1 h. The contents were then filtered through Buchner funnel.

3.8.1.10.1 Estimation of calcium

Calcium in the extract was estimated according to the method of Chopra and Kanwar (1982).

To 25 ml extract, 2-3 crystals of carbamate and 5 ml of 16% NaOH solution were added. Then, it was titrated with 0.0 IN EDTA (Appendix p VI) using Murexide indicator powder (Appendix p VI) till colour changed from orange red to purple.

3.8.1.10.2 Estimation of magnesium

To 25 ml extract, 1 ml of NaCN (2%) was added. Then 5 ml ammonium chloride-ammonium hydroxide buffer was added followed by titration with 0.01 N EDTA (Appendix p VI), using eriochrome black T as indicator, whose colour changed from green to wine red (Chopra and Kanwar, 1982).

3.8.1.11 Estimation of CEC

Cation exchange capacity of the soil samples was determined by the method of Ganguly (1951).

10 g of soil was placed in a flask to which 10 ml of 2N HCl was added. It was shaken for 1/2h and then passed through filter paper. In

order to make the soil chloride-free, it was repeatedly washed with distilled water. It was transferred to another flask to which 10 ml saturated KCl was added and kept over night. Then, it was titrated with 0.1 N NaOH (Appendix p VII) using phenolphthalein as indicator. From the amount of sodium hydroxide required, the cation exchange capacity of the soil samples was calculated as follows :

$$\text{CEC} = \frac{\text{Volume of 0.1 N NaOH} \times \text{N of NaOH}}{\text{Weight of the soil sample}}$$

3.8.1.12 Water soluble salts

In irrigated areas it is very important to know the salt content of the soils because these soils are in danger of becoming saline or alkaline. Of the various salt constituents of the soil chlorides, sulphates, carbonates bicarbonates and nitrates were determined.

3.8.1.12.1 Estimation of sulphate

It was estimated in the soil extract (1:5). To 50 ml of extract, 2.5 ml conditioning reagent (Appendix p VII) was added. After adding a small amount of barium chloride, it was shaken and then read with the help of a napthalometer.

$$mg/l\ SO_4 = \frac{mg\ SO_4 \times 1000}{ml\ sample}$$

3.8.1.12.2 Estimation of chloride

It was estimated in the extract (1:5). To the 50 ml sample, 0.5 ml K_2CrO_4 indicator (Appendix p VII) was added. Then, it was titrated with 0.0141 N silver nitrate (Appendix p VII) and calculated as follows :

$$mg/l\ Cl = \frac{(A-B) \times 0.0141 \times 35{,}450}{ml\ sample}$$

Where A = titration for sample

B = titration for blank

3.8.1.12.3 Estimation of carbonates and bicarbonates

Estimation of carbonates and bicarbonates were done following the method of Richards (1954).

For the estimation of carbonates, 50 ml of extract (1:5) was taken in a conical flask and 2 drops of phenolphthalein indicator (Appendix p VII) were added. Appearance of pink colour indicated the presence of carbonate. It was titrated with 0.01 N H_2SO_4 till the solution became colourless.

To the colourless extract, a few drops of methyl red indicator (Appendix p VII) were added. The yellow coloured extract was titrated with 0.01 N H_2SO_4 (Appendix p VII). The final colour was changed to rose red.

Calculation :

a) Carbonates (meq/l)

$$= 2y \times \text{normality of } H_2SO_4 \times \frac{1000}{\text{ml of aliquot}}$$

$$= 2y \times 2$$

b) Bicarbonates (meq/l)

$$= (Z - 2Y) \times \text{normality of } H_2SO_4 \times \frac{1000}{\text{ml of aliquot}}$$

$$= Z - 2Y \quad \times 2$$

Where Y = reading of burette for the titration of carbonates

Z = reading of burette for the titration of bicarbonates

3.8.1.13 Estimation of total dissolvcd salts (TDS)

This was determined to evaluate the concentration of total dissolved solids present in the soil. For this, 50 ml extract of the sample (1:5) was taken in a weighed beaker which was kept in an oven for the evaporation of water. After complete evaporation, it was reweighed and the amount of dissolved salts was calculated by subtracting the initial weight of beaker.

3.8.1.14 Estimation of Sodium adsorption ratio (SAR)

Irrigation waters contain dissolved salts which are in ionized form. The ions usually present are sodium, calcium and magnesium as cations and bicarbonates, carbonate, sulphate and chloride as anions. If water contains a higher proportion of sodium it produces a higher alkali hazard whereas a lower proportion of sodium and a corresponding higher proportion of calcium and magnesium involves a low hazard. In case of alkali soils the sodium ions are adsorbed and these accumulate in the soil and make its tilth and permeability very poor. Sodium adsorption ratio was calculated as described below :

$$SAR = \frac{Na^{+}}{\sqrt{\dfrac{Ca_2^{2+} + Mg^{2+}}{2}}}$$

where Na^+, Ca^{2+} and Mg^{2+} represent the concentration s of these ions in milliequivalents per litre.

3.8.2 Chemical analysis of irrigant

The analysis of irrigation water was carried out according to Standard Methods (1975). The following parameters were studied to ascertain the quality of irrigant (Table 6-7).

1. Total dissolved solids
2. Electrical conductivity (u mhos/cm)
3. pH
4. Biochemical oxygen demand (mg/l)
5. Chemical oxygen demand (mg/l)
6. Total hardness (mg/l)
7. Calcium (mg/l)
8. Magnesium (mg/l)
9. Potassium (mg/l)
10. Sodium (mg/l)
11. Bicarbonate (mg/l)
12. Carbonate (mg/l)
13. Chloride (mg/l)
14. Sulphate (mg/l)

Table 6. Irrigation water quality, all determinations in mg/l or as specified.

Parameters	10.11.88 GW	10.11.88 TE	15.12.88 GW	15.12.88 TE	15.01.89 GW	15.01.89 TE	15.02.89 GW	15.02.89 TE	15.03.89 GW	15.03.89 TE	15.11.89 GW	15.11.89 TE	25.12.89 GW	25.12.89 TE	25.01.90 GW	25.01.90 TE	25.02.90 GW	25.02.90 TE	25.03.90 GW	25.03.90 TE
TDS	756	722	910	870	900	996	807	771	770	782	950	1050	896	924	885	840	820	960	1200	1160
EC*	1290	1100	1160	1020	1100	1062	992	810	900	820	962	853	1168	1024	1124	934	960	866	1100	927
pH	8.4	7.9	8.3	8.6	8.4	8.1	8.8	8.4	8.4	8.2	7.9	8.2	8.4	8.6	8.2	7.8	8.3	8.5	8.4	8.3
BOD	5.1	4.2	4.3	5.3	4.5	4.2	4.2	4.0	4.0	3.0	4.5	3.0	5.1	4.0	5.0	3.0	3.6	2.8	5.1	4.0
COD	39	72	41	81	37	69	41	75	35	79	36	70	39	84	39	80	46	88	48	80
Calcium	13.6	34.4	15.2	49.7	16.3	56.9	18.4	52.9	14.4	57.7	14	50	15	52	17	52	16	40	14	30
Magnesium	52.4	48.4	57.6	52.2	48.9	47.1	61.6	56.2	58.4	50.0	81.0	70	68	76	68	60	88.2	80	99	90
Potassium	9	13	8	12	9	14	-	7	7	9	6	13	-	7	5	8	-	9	6	11
Sodium	74	83	71	77	82	90	76	81	90	96	68	72	80	84	53	60	76	84	73	78
Bicarbonate	102	104	107	116	126	131	123	129	112	117	65	71	103	106	93	95	102	112	123	129
Carbonate	-	-	-	19	-	-	-	-	-	10	-	-	-	-	-	13	-	-	-	-
Chloride	153.4	162.7	116.9	126.9	71.9	129.9	117.9	151.9	121.9	146.9	158.2	192.6	156.0	162.0	183.2	188.4	152.1	163.9	157.9	178.6
Sulphate	78	82	84	86	90	93	86	88	84	89	72.3	76.4	78	84	74.3	76.4	80.1	84.5	82.0	102.3
Phosphate	0.12	0.54	0.01	0.66	0.23	0.79	0.21	0.61	0.01	0.73	0.22	0.82	0.08	0.72	0.01	0.76	0.06	0.85	0.01	0.78

* (μ mhos/cm)

Table 7. Irrigation water quality (contd.)

Parameter	20.11.90	27.12.90	27.01.91	27.02.91
	Treated effluent			
pH	8.3	8.4	8.2	8.5
E.C.	1132	1128	936	924
Ca^{++}	50	48	40	15
Mg^{++}	68	78	90	76
TDS	940	1026	927	963
SO_4^{--}	89	72	72.6	68
PO_4^{---}	0.56	0.82	0.62	0.83
HCO_3^-	92	94	102	89
CO_3^-	12	-	-	8
Cl^-	173	165.94	172.64	165.0
Na^+	83	69	68	72
COD	78	86	76	52
BOD	3.0	3.2	3.0	3.4

3.8.2.1 Estimation of total dissolved solids (TDS)

100 ml of water sample was taken in a weighed porcelain dish. It was evaporated to dryness on a water bath. Drying was finished in an oven at 105°C. Then it was cooled in a dessicator and weighed. The weight of the residue represented the total dissolved solids.

3.8.2.2. Estimation of electrical conductivity (EC)

Samples were directly read with the help of a conductivity meter by taking the solution in a beaker. The apparatus was adjusted to a known temperature (25°C) of the solution.

3.8.3 Measurement of pH

It was determined with the help of pH meter, after the latter was checked and adjusted with standard buffer of known pH.

3.8.2.4 Determination of bio-chemical oxygen demand (BOD)

It is widely used to determine the pollution power or strength of sewage and industrial waste in terms of the oxygen that micro organisms will require if discharged into natural water.

Different volumes of the effluent samples were placed in the BOD bottles (300 ml) to get several dilutions of the samples to obtain the required depletions ranging between 0.1 to 1.0%. These bottles were filled with distilled water, stoppered and incubated for five days in the incubator maintained at 20°C. The dissolved oxygen of these samples was determined by first adding 2 ml of manganese sulphate solution (Appendix p IV) followed by 2 ml alkaliazide reagent (Appendix p IV) by means of a graduated pipette by dipping its end well below the surface of the liquid. The bottles were stoppered and mixed well by inverting them. The bottles were allowed to stand till the precipitate settled half way, leaving a clear supernatant above the manganese hydroxide floc. The stopper was removed and 2 ml sulphuric acid was immediately added. Each bottle was restoppered and the contents were mixed by gentle inversion until dissolution was complete. 203 ml of the sample was taken in a 500 ml conical flask, 2 ml starch indicator added and titrated against 0.025N sodium thiosulphate solution till the disappearance of the blue colour. The reading of sodium thiosulphate used up was indicative of the dissolved oxygen of the sample in mg l^{-1}. The BOD was calculated using the following relationship.

$$\text{mg. } l^{-1} \text{ BOD} = \frac{D_1 - D_2}{P}$$

Where D_1 and D_2 are the dissolved oxygen of the diluted samples 15 min after the preparation of the sample and after 5 days of incubation.

respectively and P is the decimal fraction of the sample used.

3.6.2.5 Estimation of chemical oxygen demand (COD)

It is a measure of oxygen equivalent of that portion of the organic matter in a sample which is susceptible to oxidation by a strong chemical oxidant.

0.4 g of mercuric sulphate was placed in a refluxing flask and 20 ml of the sample was added. These were mixed well and 10 ml of 0.25 N potassium dichromate (Appendix p IV) was added to it followed by 30 ml of sulphuric acid and a small amount of silver sulphate. A blank was run using distilled water instead of the sample. These were subjected to reflux for 2h, cooled and then diluted to about 100 ml with distilled water. The contents were then titrated against standard ferrous ammonium sulphate solution (Appendix p IV), using ferroin as indicator (Appendix p IV).

Calculation

$$\text{mg } l^{-1}\text{COD} = \frac{(a - b) \times c \times 8{,}000}{\text{ml sample}}$$

Where a = ml of ferrous ammonium sulphate used for blank titration

b = ml of ferrous ammonium sulphate used for sample titration

c = Normality of ferrous ammonium sulphate solution.

3.8.2.6 Estimation of total hardness

It is the characteristics of water that represents the total concentration of calcium and magnesium ions expressed as calcium carbonate. 50 ml of the sample was taken into a conical flask and pH was maintained at 10 + 1 by the addition of buffer. Then, it was titrated with 0.01M EDTA (ethylene diamine tetracetic acid) using Eriochrome Black T as indicator (Appendix p IV). Pink colour was changed to blue. It was calculated as follows:

Hardness (EDTA) as mg $CaCO_3/1$

$$\frac{A \times B \times 1000}{\text{ml sample}}$$

Where A = ml titration for sample

B = mg $CaCO_3$ equivalent to 1.0 ml EDTA titrant

3.8.2.7 Estimation of calcium

In a conical flask, 50 ml of water sample was taken and neutralised with acid. It was boiled for 1 min and then cooled. Then, 2 ml of 1N sodium hydroxide solution (Appendix p II) was added to maintain the pH at 12-13. After the addition of 1-2 drops of ammonium purpurate indicator (Appendix p IV), it was titrated slowly with 0.01M/EDTA (Appendix p IV) and calculated as follows:

$$\text{mg Ca/l} = \frac{A \times B \times 400.8}{\text{ml sample}}$$

$$\text{Calcium hardness as mg } CaCO_3 / l = \frac{A \times B \times 1{,}000}{\text{ml sample}}$$

Where A = ml titration for sample

B = mg $CaCO_3$ equivalent to 1.0 ml EDTA titrant at the calcium indicator end point.

3.8.2.8 Determination of magnesium

Magnesium was calculated by the following formula:

mg/l Mg = total hardness (as mg $CaCO_3$/l) - calcium hardness (as mg $CaCO_3$/l) x 0.243

3.8.2.9 Estimation of potassium

The determination of potassium was carried out directly with the help of a flame photometer and a standard curve prepared by taking known concentrations of K.

A stock solution of 1,000 ppm K was prepared by dissolving 1.908 g KCl in a litre of distilled water. Dilute solutions containing 2,5,10,15 and 25 ppm K were prepared from the stock solution. The standard curve was prepared plotting the flame photometer readings against concentrations of K.

3.8.2.10 Estimation of sodium

As described earlier on p.

3.8.2.11 Estimation of carbonates and bicarbonates

50 ml water sample was taken in a clean flask. To this, 5 drops of phenolphthalein indicator (Appendix p VII) were added. The appearance of pink colour indicated the presence of carbonates.

Then it was titrated against 0.1N sulphuric acid (Appendix p VII) till the solution became colourless.

To the colourless solution from the above titration, 2 drops of methyl red solution (Appendix p VII) were added It was again titrated against 0.01N sulphuric acid till the colour changed from yellow to rose red. This indicated the bicarbonate concentration.

Calculations as described earlier

3.8.2.12 Estimation of chloride

50 ml of water sample was taken in a flask and to this 0.5 ml potassium chromate indicator (Appendix p VII) was added. It was titrated against 0.0141N silver nitrate solution (Appendix p VII). Chloride concentration in the sample was calculated as follows.

$$mg/l\ Cl = \frac{(A-B) \times 0.0141 \times 35,450}{ml\ sample}$$

Where, A = ml titration for sample

B = ml titration for blank

3.8.2.13 Estimation of sulphate

50 ml of sample was taken in a flask and, to this, 2.5 ml conditioning reagent (Appendix p VI) and a small amount of barium chloride was added. After shaking for 1 min, it was read with the help of a napthalometer.

Standard sulphate solution was made by dissolving 147.9 g sodium bisulphate ($NaH\ SO_4$) in sufficient distilled water and making upto 100 ml. From this, 10,20,30, and 40 ppm dilutions were prepared. Turbidity was developed by adding 2.5 ml conditioning reagent and a small amount of barium chloride. A standard curve was prepared by plotting the readings for each dilution, using a napthalometer.

3.8.3 Chemical analysis of plant

Plant parts were subjected to various chemical analysis at different growth stages of the crop.

3.8.3.1 Leaf analysis

Fresh leaves at tillering, heading and milky grain stages were analysed for proline content in Experiments 2 and 3 (due to water stress treatment)

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3.8.3.1.1 Estimation of proline

It was determined in flag leaves according to the method of Bates*et.al.* (1973).

1) Approximately 500 mg leaf material was homogenised in 10 ml of 3% sulfos alicylic acid and the homogenate was filtered through Whatman No. 42 filter paper.
2) 5 ml filterate was reacted with 2 ml acid ninhydrin (AppendIx p I) and 2 ml glacial acetic acid in a test tube for 1 h at 100°C (Water bath) and the reaction was terminated in an ice-box.
3) The reaction mixture was extracted in 5 ml of toluene after mixing was vigorously by a test tube stirrer for 15-20 seconds.
4) The chromophore containing toluene was aspirated from the aqueous

phase. After coming to room temperature, the absorbance was read at 520 nm using toluene for blank

5) The proline concentration was determined, on fresh weight basis, from a standard curve prepared by taking different concentrations of pure proline.

3.8.3.2 Grain analysis

The powdered samples of grain were analysed for:

1. Total carbohydrate content (%)
2. Total protein content (%)
3. Lysine content (%)
4. Heavy metals (µg/g)

The total carbohydrate (q/ha) and total protein yield (q/ha) were also calculated by multiplying the percentage with total grain yield and dividing it by hundred.

3.8.3.2.1 Estimation of total carbohydrate

Soluble and insoluble carbohydrates were extracted according to the method of Yih and Clark (1965) and estimated by the method of Dubois *et al.* (1956).

The dry samples were ground to fine powder and passed through a 72 mesh sieve. The powder was stored in polythene bages and was dried again overnight in an oven at 80°C before analysis.

50 mg powder of each sample was transferred to a glass centrifuge tube. To this, 5 ml of ethyl alcohol was added and then heated on water bath at 60°C for 10 min. The sample was cooled and centrifuged at 4,000 rpm for 10 min. The supernatant was poured into 25 ml volumetric flask with three washings and the final volume was made up with 80% alcohol. The residue was preserved in the same tube for the estimation of insoluble carbohydrate. 1 ml of this extract was transferred to a test tube and evaporated to dryness on a water bath. The test tube was then cooled and 2 ml distilled water was added. The extract was used for the estimation of soluble carbohydrate.

To the residue, 5 ml of 1.5 N sulphuric acid (Appendix p I) was added and then heated on waterbath at 100°C for 2h. After cooling, it was centrifuged at 4,000 rpm. The supernatant was collected in a 25 ml volumetric flask with three washings. The final volume was made up with distilled water. 1 ml of the extract and 1 ml of distilled water were taken into a test tube to estimate insoluble carbohydrate.

To each test tube, containing the extract of soluble or insoluble carbohydrate, 1 ml of 5% distilled phenol was pipetted followed by the addition of 5 ml concentrated sulphuric acid. Then it was cooled by placing in chilled water and, after 30 min, optical density of yellowish orange colour was measured at 490 nm on a "Spectronic 20" colorimeter. A blank was run simultaneously. The carbohydrate contents were calculated by comparing the optical density of the sample with a calibration curve plotted by taking known dilutions of a standard solution of chemically pure glucose.

3.8.3.2.2 Estimation of total protein

Protein was estimated following the method of Lowry *et al.* (1951).

Grain powder was kept in an oven at 80°C overnight. After cololing, a 50 mg sample was transferred to a mortar to which 1 ml of distilled water was added. The powder was ground well and transferred to a centrifuge tube with repeated washings and the volume was made upto 5 ml with distilled water. The extract was then centrifuged at 4,000 rpm for 5 min and the supernatant was collected for soluble protein.

To the residue, 5 ml of 5% trichloroacetic acid was added. The solution was allowed to stand at room temperature for 30 min with thorough shaking. It was then centrifuged at 4,000 rpm for 10 min and the supernatant was discarded. To the pellet, 5 ml of 1N sodium hydroxide (Appendix p II) was added and mixed well by shaking. Then, the residue was kept on waterbath at 80°C for 30 min. After centrifuging at 4,000 rpm, the supernatant was collected with three washings with 1N sodium hydroxide in 25 ml volumetric flask. The volume was made upto the mark with 1N sodium hydroxide and then it was used for the estimation of insoluble protein.

1 ml of water extract was transferred to a 10 ml test tube and 5 ml

of reagent C (Appendix p I) was added. The solution was mixed well and allowed to stand for 10 min at room temperature and 0.5 ml of reagent E (Appendix p I) was added rapidly with immediate mixing. After 30 min the blue coloured solution was transferred to a colorimetric tube and the percent transmittance was read at 660 nm on a "Spectronic 20" colorimeter. A blank was run with each sample. The soluble protein contents were estimated by comparing the optical density of each sample with a calibration curve plotted by taking known dilution of a standard solution of egg albumen. 1 ml of sodium hydroxide extract was transferred to a 10 ml test tube 5 ml of reagent D (Appendix p I) was added to it. The solution was mixed and allowed to stand for 10 min at room temperature. 0.5 ml reagent E (Appendix p I) was added rapidly with immediate mixing. After 30 min, the intensity of the blue coloured solution was measured on a "Spectronic - 20" colorimeter as in the case of soluble protein.

3.8.2.3 Estimation of lysine

Lysine content in the grain protein was estimated by the colorimetric method of Villegas and Mert (1971) and Tsai *et al* .(1972).

1) The powdered grain samples were defatted with hexane for 6 h in a Soxhlet apparatus. The samples were then air dried and ground further to fine powder (80-100 mesh) in an amalgamator.
2) 100 mg of finely ground defatted sample was weighed in a glass vial

and 5 ml of papain solution (Appendix p II) was added to it. The vials were tightly capped so as to shake the sample to wet them thoroughly with papain solution. A blank containing papain solution was run simultaneously.

3) The samples were shaken for 1 h and then incubated at 65°C. After taking them out from the incubator, the samples were shaken again for 1 h to digest them fully.

4) The hydrolysed samples after being removed from the incubator were subjected to constant shaking while being allowed to adjust to room temperature. To get a clear supernatant, each sample was centrifuged at 3,000 rpm for 5 min.

5) From the supernatant fraction, 1 ml aliquot was transferred to a centrifuge tube containing 0.5 ml of carbonate buffer, followed by addition of 0.5 ml of copper phosphate suspension (Appendix p II).

6) The mixture was shaken for 5 min and centrifuged to precipitate the excess copper phosphate.

7) 1 ml aliquot of the supernatant was pipetted into a 30 ml ~~30 ml~~ test tube and 0.1 ml of 2 chloro - 3,5 dinitro-pyridine solution (Appendix p III) was added to it and shaken well keeping the tubes well stoppered with velvet cork.

8) The reaction was allowed to proceed for 2 h at room temperature, shaking the test tube after every 30 min.

9) To acidify the reaction mixtures, 5 ml of 1.2 N HCl was added to it with proper shaking.

10) Later, 5 ml of ethyl acetate was added, the stoppered tubes were inverted 10 times to mix well. The upper phase was extrated by a syringe adopted with polyethyline tube. This step was repeated 3 times.

11) The aqueous solution containing DNPyr lysine was transferred to calibrated tubes and read on a "Spectronic - 20" colorimeter at 390 nm against a blank.

12) The lysine content of the samples was determined by using a standard calibration curve prepared in the following manner, followed by calculation on protein basis.

a) The standard curve was prepared in a range of 0 to 200 μg of lysine per ml.

b) Stock solution of lysine (2,500 μg/ml) was prepared by dissolving 62.5 mg of lysine monohydrochloride in 20 ml of carbonate buffer.

c) The stock solution was diluted with carbonate buffer to 250, 500, 750 and 1000 μg lysine per ml.

d) From each of these solutions, 1 ml aliquot was pipetted out and 4 ml of papain solution and 15 mg per ml/buffer was added to it so that the respective concentration of lysine became 0, 50, 100, 150 and 200 μg/ml.

e) From each solution, 1 ml aliquot was pipetted out into a centrifuge tube together with 0.5 ml of the solution containing amino acid mixture (Appendixp III), followed by 0.5 ml of copper phosphate suspension. The detailed procedure presented above was then applied from step (5) onwards and the standard curve was plotted.

3.9 Determination of heavy metals

Since the crop received refinery effluent, soil and grain could be expected to accumulate some heavy metals, if present in the water. Therefore, it was decided to estimate the following heavy metals, cadmium, chromium, copper, lead, nickel, vanadium and zinc.

3.9.1 Atomic absorption spectrophotometer

GBS 902 double beam Atomic Absorption Spectrophotometer was used for determining the concentration of metals in soil, water and plant (Table 8-10).

3.9.2 Reagents

Only analytical grade reagents were used throughout the study. Standard solutions were prepared using double distilled water.

3.9.3 Cleaning of glassware

Corning brand glassware was exclusively used. All possible steps were

Table 8. Heavy metals in soil samples.

Heavy metals (µg/g)	Ground water with fertiliser		Treated effluent with fertiliser		Treated effluent without fertiliser	
	A	B	A	B	A	B
Cd	----------Not detected----------					
Cr	20.52	26.31	16.52	38.96	14.42	36.69
Cu	45.26	40.29	49.52	47.29	60.52	54.69
Ni	37.42	32.29	28.42	39.63	32.82	42.29
Pb	32.16	28.24	34.26	29.62	32.29	26.52
V	9.26	16.52	22.61	54.29	26.52	58.62
Zn	122.52	118.64	136.12	129.6	132.29	126.53

A - Before sowing

B - After harvest

Table 9. Heavy metals in irrigant

Heavy metals (μg/l)	Treated effluent	Ground water
Cd	ND	ND
Cr	0.04	ND
Cu	0.016	0.012
Hg	ND	ND
Ni	0.01	ND
Pb	0.027	0.011
V	0.094	ND
Zn	0.12	0.09

ND - Not detected

Table 10. Heavy metals in grain samples

Heavy metals (μg/g)	Delfin		TL-419		Driera		HD-2204	
	TE	GW	TE	GW	TE	GW	TE	GW
Cd	----------------Not detected-------------------------------------							
Cr	84.23	62.56	82.16	61.59	78.64	56.23	88.64	58.92
Cu	14.46	8.49	15.12	7.12	15.88	9.12	16.18	8.16
Ni	72.52	52.48	73.56	56.69	67.58	52.29	68.54	48.29
Pb	18.24	14.56	17.64	16.24	16.23	14.23	18.13	16.16
V	72.54	55.29	68.58	58.29	72.16	56.16	69.18	56.34
Zn	39.26	45.19	42.59	48.66	52.19	61.48	48.29	56.53

TE - Treated effluent

GW - Ground water

taken to avoid metallic contamination from the glassware.

The glassware, namely volumetric flasks, beakers, pipettes, test tubes and sample storage bottles were washed with detergents and water, rinsed with distilled water and then immersed in a bath of 10% nitric acid for 24 h. The glassware were then rinsed with double distilled water and finally tested till they became acid free.

3.9.4 Preparation of samples for analysis

3.9.4.1 Water samples

20 ml water was taken in a conical flask. To this, 10 ml of nitric acid was added. It was placed on a hot plate for digestion. After complete digestion, total volume was made upto 100 ml. It was stored in polythene bottles after filtering through Whatman filter paper No. 42.

3.9.4.2 Soil samples

1 g of soil sample was taken in a conical flask. To this 10 ml of nitric acid was added. It was placed on a hot water plate for digestion. After 12 h of digestion, 5 ml of perchloric acid was added for complete digestion. After cooling, it was filtered and the volume was made upto 100 ml with double distilled water. After filtering through Whatman filter paper No.42, it was stored in polythene bottles for analysis.

3.9.4.3 Plant samples

500 mg of grain or leaf powder was taken in a conical flask. After adding 10 ml nitric acid, it was placed on a hot plate for digestion. After complete digestion, it was filtered. Final volume was made upto 100 ml. Then, it was filtered through Whatman filter paper No.42 and stored for analysis.

3.10 Statistical analysis

All the data were analysed statistically according to Panse and Sukhatme (1967). The most regorous `F' tests were followd in which the error due to replicates was also determined. When 'F' value was found to be significant at 5 per cent level of probability, critical difference (C.D.) was calculated. The models of the analysis of variance (ANOVA) for each of the experimental design are given in Table 11 and 12.

Tanble 11. Model analysis of variance (ANOVA) used in Experiments 1-2

Experiment 1 (Split plot design)

Source of variation	D.F.	S.S.	M.S.	F
Replications	2			
Main plot treatments (M)	1			
Error (a)	2			
Sub-plot treatments (S)	3			
Interactions (M x S)	3			
Error (b)	12			
Total	23			

Experiment 2 (Split plot design)

Source of variation	D.F.	S.S.	M.S.	F
Replications	2			
Main plot treatments (M)	1			
Error (a)	2			
Sub-plot treatments (S)	4			
Interactions (M x S)	4			
Error (b)	16			
Total	29			

Tanble 12. Model analysis of variance (ANOVA) used in Experiments 3-4

Experiment 3 (Split plot design)

Source of variation	D.F.	S.S.	M.S.	F
Replications	2			
Main plot treatments (M)	2			
Error (a)	4			
Sub-plot treatments (S)	3			
Interactions (M x S)	6			
Error (b)	18			
Total	35			

Experiment 4 (Split plot design)

Source of variation	D.F.	S.S.	M.S.	F
Replications	2			
Main plot treatments (M)	1			
Error (a)	2			
Sub-plot treatments (S)	3			
Interactions (M x S)	3			
Error (b)	12			
Total	23			

D.F. Degree of freedom
S.S. Sum of squares
M.S. Mean of square
F. Variance ratio

CHAPTER 4

EXPERIMENTAL RESULTS

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CHAPTER 4

EXPERIMENTAL RESULTS

4.1 Experiment 1

In this split plot field experiment, the performance of three varieties of triticale (Delfin, TL-419, Driera) and one wheat check (HD-2204) was compared under treated effluent and ground water irrigation. The data are summarized in Tables 13 to 32 and are described below:

4.1.1 Germination

On comparing the main plot means, as also the main plot means at the same level of sub-plot, it was revealed that their effect on germination percentage was non significant (Table 13).

All the varieties gave critically different values. HD-2204 showed the highest germination percentage followed by Delfin, while TL-419 showed the lowest germination.

The varieties gave different values with ground water as well as treated effluent. Among the triticales, maximum germination was noted in Delfin and minimum, in TL-419 under both treated effluent and ground water, with the wheat check surpassing the triticales.

Table 13. Effect of ground water and treated effluent on germination (%) of triticale and wheat.

Sub-plots (Varieties)	Main plots		Mean
	Ground water	Treated effluent	
Delfin	88.55	88.54	88.54
TL-419	84.22	84.22	84.22
Driera	85.27	85.28	85.27
HD-2204	90.28	90.31	90.29
Mean	87.08	87.08	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	N.S.
Sub-plot marginal means (S)	0.360
Main plot means at the same level of sub-plots (M x S)	N.S.
Sub-plot means at the same level of main plot (S x M)	0.539

N.S. Non-significant

4.1.2. Growth parameters

Five growth parameters, (shoot length, leaf number, tiller number, fresh weight and dry weight) were studied at tillering, heading and milky grain stages. All the growth attributes at all the stages were significantly affected. Varietal differences were also significant for most of the parameters.

4.1.2.1. Shoot length per plant

It is evident from Tables 14 that, at the main plot level, treated effluent significatly increased plant shoot length by 5.87, 5.61 and 6.75% at tillering, heading and milky grain stages respectively compared with ground water application.

Among the varieties tested (at sub-plot level), Delfin gave the highest value for shoot length at all the three stages which was 27.09, 23.52 and 41.60% more than HD-2204 wheat. The remaining two varities were intermediate in their performance.

On comparing the main plot means at the same level of sub-plot, it was observed that treated effluent proved better as compared to ground water at all the three growth stages and in all the four varieties tested.

When different sub-plot means at the same level of main plot were taken into consideration, it was found that all the varieties, gave different values with treated effluent or ground water at all the three growth stages, except TL-419 and Driera whose performance was at par witheach other at heading in

Table 14 . Effect of ground water and treated effluent on shoot length (cm) of triticale and wheat at three stages of growth.

Sub-plots (varieties)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
Delfin	72.16	75.23	73.69	95.33	100.46	97.89	120.66	127.53	124.09
TL-419	65.03	69.36	67.19	89.06	92.83	90.94	103.60	108.73	106.16
Driera	67.73	71.70	69.71	90.40	94.26	92.33	108.96	121.83	115.39
HD-2204	56.00	59.96	57.98	75.80	82.70	79.25	85.90	89.36	87.63
Mean	65.23	69.06		87.64	92.56		104.78	111.86	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.491	0.821	0.621
Sub-plot marginal means (S)	0.887	1.044	0.771
Main plot means at the same level of sub- plot (MxS)	1.255	1.476	1.090
Sub- plot means at the same level of main plot(SxM)	1.169	1.470	1.092

ground water treated plots. Delfin gave an increase of 25.46, 21.47 and 42.71% over HD-2204 with treated effluent and 28.85, 25.76 and 40.46% with ground water at tillering, heading and milky grain stages respectively. There was a linear increase in plant shoot length from tillering to milky grain stage in all the varieties.

4.1.2.2. Leaf number per plant

Treated effluent increase leaf production significantly and leaf number was 17.58, 15.15 and 19.49% higher at the three successive stages in comparison with ground water (Table 15).

At each of the three growth stages, leaf number was maximum in Delfin (74.25, 81.83, 135.32% more than wheat which gave the lowest value at the three successive stages).

Considering the values of main plot means at the same level of sub-plot, it was observed that at all the three growth stages, treated effluent, gave higher values for leaf number in all the varieties.

Maximum leaf number was noted in Delfin in both main plots, Which was 86.54, 90.13 and 148.49% higher in ground water and 64.80, 75.13 and 125.39% higher in treated effluent in comparison with HD-2204 wheat. At tillering stage, TL-419 and Driera responded equally in ground water as well as treated effluent. Leaf number gradually increased from tillering to heading stage but decreased at milky grain stage.

Table 15. Effect of ground water and treated effluent on leaf number of triticale and wheat at three stages of growth.

Sub-plots (varieties)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
Delfin	25.93	29.83	27.88	28.33	32.33	30.33	24.00	28.76	26.38
TL-419	20.60	23.93	22.26	22.86	25.56	24.21	17.86	20.90	19.38
Driera	21.93	25.00	23.46	24.50	27.96	26.23	20.73	23.90	22.31
HD-2204	13.9	18.10	16.00	14.90	18.46	16.68	09.66	12.76	11.21
Mean	20.59	24.21		22.64	26.07		18.06	21.58	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	1.272	1.132	0.439
Sub-plot marginal means (S)	0.856	0.652	0.836
Main plot means at the same level of sub- plot (MxS)	1.210	0.922	1.183
Sub- plot means at the same level of main plot(SxM)	1.559	1.309	1.094

4.1.2.3. Tiller number per plant

Treated effluent significantly produced more tiller than ground water (Table 16). It was 24.61, 22.15 and 23.11% higher in effluent when compared with ground water at the three successive stages of sampling.

Among sub-plot treatments, it was noted that Delfin produced more tillers compared to other varieties. An increase of 79.44, 98.61 and 84.38% was observed in Delfin when compared with HD-2204, while it showed an increase of 29.89, 39.69 and 29.76% over Driera, the other variety of triticale, at the three successive stages of growth.

Treated effluent proved better, with all the varieties at all the three stages, than ground water. Treated effluent, in the case of Delfin, recorded an increase of 27.31, 10.49 and 12.86% over ground water at the three successive stages. On the other hand, treated effluent with HD-2204 gave an increase of 38.41, 40.47 and 39.47% indicating the better tiller production capability of wheat in treated effluent than in ground water each of the three stages of growth.

Delfin gave maximum tiller at all the three stages and recorded an increase of 88.30, 126.90 and 120.56% with ground water, and 73.20, 78.47, 78.47% with treated effluent, over HD-2204. In addition, Delfin showed an increase of 35.24, 31.13 and 31.13% with treated effluent, and 23.62, 50.55 and 46.69% with ground water, over Driera which performed better than TL-419 at the three successive growth stages under both main plot treatments.

Table 16. Effect of ground water and treated effluent on tiller number of triticale and wheat at three stages of growth.

Sub-plots (varieties)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
Delfin	8.53	10.86	9.69	9.53	10.53	10.03	9.33	10.53	9.33
TL-419	5.86	6.86	6.36	5.23	6.43	5.83	5.03	6.23	5.63
Driera	6.90	8.03	7.46	6.33	8.03	7.18	6.36	8.03	7.19
HD-2204	4.53	6.27	5.40	4.20	5.90	5.05	4.23	5.90	5.06
Mean	6.42	8.00		6.32	7.72		6.23	7.67	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.485	0.310	0.684
Sub-plot marginal means (S)	0.697	0.521	0.441
Main plot means at the same level of sub- plot (MxS)	0.986	0.734	0.623
Sub- plot means at the same level of main plot(SxM)	0.955	0.694	0.823

4.1.2.4. Fresh weight per plant

It may be noted from the Table 17 that higher weight was obtained under treated effluent application and the values were 15.99, 19.16 and 7.54% more over ground water treatment at the three growth stages.

Being taller with more leaf and tiller number, Delfin recorded the highest fresh weight compared to the other varieties of triticale as well as wheat. It recorded an increase of 59.70, 42.15, 42.26% over wheat at tillering, heading and milky grain stages respectively.

Under treated effluent, all the varieties tested showed higher fresh weight as compared to ground water. The effect of treated effluent x Delfin was followed by treated effluent x Driera. Grown under treated effluent, Delfin and HD-2204 showed an increase of 14.18, 15.11, 5.79% and 25. 27, 32.39, 12.68% over ground water at the three growth stages.

While considering the other interaction (S x M), it was noted that all the varieties gave critically different values with ground water as well as treated effluent. Like the other parameters, here again Delfin proved best and recorded an increase of 67.95, 53.57, 78.02% over HD-2204 at the three successive samplings under ground water application while it showed a comparatively lower increase of 53.08, 33.53 and 67.14% over HD-2204 at the three successive stages under treated effluent applicaton.

Tabel 17. Effect of ground water and treated effluent on fresh weight (g) of triticale and wheat at three stages of growth.

Sub-plots (varieties)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
Delfin	23.06	26.33	24.69	34.80	40.06	37.43	48.28	51.08	49.68
TL-419	19.23	21.56	20.39	28.00	32.56	30.28	37.72	40.47	39.09
Driera	20.53	23.70	22.11	30.33	35.33	32.83	42.15	44.86	43.50
HD-2204	13.73	17.20	15.46	22.66	30.00	26.33	27.12	30.56	28.84
Mean	19.13	22.19		28.94	34.48		38.81	41.74	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.432	0.997	1.214
Sub-plot marginal means (S)	0.710	0.670	0.583
Main plot means at the same level of sub- plot (MxS)	1.004	0.948	0.824
Sub- plot means at the same level of main plot(SxM)	0.949	1.221	1.333

4.1.2.5. Dry weight per plant

Higher dry weight was observed under treated effluent application at all the three growth stages. An increase of 40.55, 20.47 and 17.21% with effluent treatment was observedover ground water application at tillering, heading and milky grain stages respectively (Table 18).

Delfin accumulated consistently higher dry matter than the other varieties of triticale and HD-2204 throughout the growth period. All the varieties differed critically in this respect, except TL-49 and Driera at heading. Delfin showed an increase of 68.77, 36.11 and 91.24% over HD-2204 at the Three stages of growth.

It was noted that treated effluent treatment interacted better with all the varieties tested and accumulated more dry weight compared with ground water. Delfin was followed by the Driera under treated-effluent conditions at all the three stages and showed critically different values compared with those obtained with ground water. Treated effluent x Delfin showed an increase of 41.44, 21.93 and 15.99% over ground water x Delfin at the three successive stages, whereas treated effluent x HD-2204. recorded an increase of 34.98, 24.28 and 19.81% over ground water x HD-2204.

All the varieties gave statistically different values, except TL-419 and Driera at heading stage, under ground water as well as treated effluent application. The variety Delfin proved best and showed an increase in dry weight of 64.18, 37.46 and 94.62% under ground water and 72.04, 34.86 and

Table 18. Effect of ground water and treated effluent on dry weight (g) of triticale and wheat at three stages of growth.

Sub-plots (varieties)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
Delfin	5.96	8.43	7.19	8.66	10.56	9.61	20.63	23.93	22.28
TL-419	4.36	6.30	5.33	7.59	8.76	8.17	13.33	15.03	14.18
Driera	4.90	6.86	5.88	7.73	9.33	8.53	16.33	19.70	18.01
HD-2204	3.63	4.90	4.26	6.30	7.83	7.06	10.60	12.70	11.65
Mean	4.71	6.62		7.57	9.12		15.22	17.84	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.179	0.676	0.363
Sub-plot marginal means (S)	0.395	0.432	0.439
Main plot means at the same level of sub- plot (MxS)	0.559	0.611	0.621
Sub- plot means at the same level of main plot(SxM)	0.508	0.812	0.626

88.42% under treated effluent over HD-2204 at the three stages of growth. On the other hand, Delfin recorded an increase of 21.63, 12.03 and 26.33% with ground water and 22.88, 13.18 and 21.47% with treated effluent over Driera.

4.1.3 Net assimilation rate (NAR)

The rate of assimilation was more under treated effluent compared to ground water at all three stages of growth (Table 19).

All the varieties showed statistically different values at each of the three sampling stages, except TL-419 and HD-2204 which were at par at tillering. Delfin recorded the maximum value followed by Driera while TL-419 gave the poorest performance. The former variety recorded an increase of 25.98, 12.87 and 13.72% over HD-2204.

While considering the M x S interaction effect it was noted that treated effluent had a higher NAR compared to ground water in all the varieties at tillering, heading as well as milky grain stages. Delfin together x treated effluent recorded maximum value and showed an increase of 6.96, 5.67 and 7.39% over Delfin x ground water at the three samplings.

All the varieties differed significantly under both treatments, except TL-419 and HD-2204 which were at par at tillering and milky grain stages under ground water as well as treated effluent, Delfin recording the maximum net assimilation rate followed by Driera at all the three samplings. There was increase in the rate of assimilation from tillering to heading and then it

Table 19. Effect of ground water and treated effluent on net assimilation rate (NAR x 10^{-4} g/cm²d) of triticale and wheat at three stages of growth

Sub-plots (varieties)	Stages of sampling								
	Tillering (T)(60-75 d)			Heading (H) (75-90 d)			Milky grain (M) (90 - 105 d)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
Delfin	4.31	4.61	4.46	5.46	5.77	5.61	3.92	4.21	4.06
TL-419	3.41	3.73	3.57	4.72	4.95	4.83	3.33	3.62	3.47
Driera	4.03	4.26	4.14	5.27	5.52	5.39	3.71	3.95	3.83
HD-2204	3.42	3.67	3.54	4.87	5.07	4.97	3.42	3.72	3.57
Mean	3.79	4.06		5.08	5.32		3.59	3.87	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.029	0.042	0.128
Sub-plot marginal means (S)	0.047	0.061	0.041
Main plot means at the same level of sub- plot (MxS)	0.067	0.087	0.059
Sub- plot means at the same level of main plot(SxM)	0.063	0.084	0.132

decreased at milky grain stage.

4.1.4. Yield parameters

The treatments showed significant effect on yield parameters. The data are presented in Tables 20 to 27 and are briefly described below.

4.1.4.1. Ear number per plant

It is evident from Table 20 that treated effluent produced more ears per plant than ground water, being 29.27% more in the former than the latter.

Among the varieties, Delfin produced maximum ears. The value was 43.09 and 92.21% higher than Driera and HD-2204 respectively.

Under treated effluent, all varieties produced more ears than ground water. Delfin proved best and had 22.40% more ears in treated effluent, while HD-2204 produced the least ear number and gave higher value in treated effluent than in ground water.

Maximum ears were produced by Delfin under treated effluent as well as ground water. The values given by this variety critically different from other varieties under both conditions. The lowest number of ears was noted in HD-2204 under both treatments. In Delfin, showed an increase of 63.07% compared with HD-2204. Under treated effluent. On the other hand the same variety (Delfin) gave an increase of 145.32% over HD-2204 in ground water treatment. Delfin also recorded 39.00% more ears than Driera in treated and

Table 20. Effect of ground water and treated effluent on ear number of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Main plots: Treated effluent	Mean
Delfin	8.66	10.60	9.63
TL-419	5.23	6.23	5.73
Driera	6.23	7.23	6.73
HD-2204	3.53	6.50	5.01
Mean	5.91	7.64	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.124
Sub-plot marginal means (S)	0.561
Main plot means at the same level of sub-plots (M x S)	0.794
Sub-plot means at the same level of main plot (S x M)	0.696

effluent 46.61% more ears in ground water. Production of ears by TL-149 and HD-2204 under treated effluent was at par.

4.1.4.2. Length per ear

It is evident from the Table 21 that treated effluent produced longer ears than ground water. Ear length was 8.80% more with effluent in comparision with ground water.

Considering the sub-plots, it emerged that Delfin produced longest ears and the value was critically different from those of all other sub-plot treatments and an increase of 65.51 and 18.19% over HD-2204 and Driera respectievely was noted.

Treated effluent produced more ear length. Than ground water in all varieties except HD-2204. Under both irrigations, Delfin produced ears of maximum length, and HD-2204 of minimum length. with treated effluent Delfin and Driera recorded an increase of 7.59 and 9.55% over their respective counterparts.

Ears of maximum length were produced in Delfin under both treatment being 62.18 and 68.81% longer than in HD-2204 under ground water and treated effluent respectively. Delfin showed an increase of 17.17 and 19.30% compared to Driera interacting with treated effluent and ground water respectively.

Table 21. Effect of ground water and treated effluent on length per ear of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Treated effluent	Mean
Delfin	24.10	25.93	25.01
TL-419	17.66	20.16	18.91
Driera	20.20	22.13	21.16
HD-2204	14.86	15.36	15.11
Mean	19.20	20.89	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.882
Sub-plot marginal means (S)	0.690
Main plot means at the same level of sub-plots (M x S)	0.976
Sub-plot means at the same level of main plot (S x M)	1.160

4.1.4.3. Ear weight per plant

With regard to main plot, ear weight was recorded under treated effluent conditions which was 11.03% higher compared to ground water application (Table 22).

On comparing the sub-plot means, it was found that Delfin proved best followed by TL-419, Driera and HD-2204 in that order. Delfin showed an increase of 100.90% in ear weight over HD-2204. TL-419 followed closely, giving only 15.23 lower ear weight than Delfin.

Treated effluent as well as ground proved best for Delfin, followed by TL-419. Under treated effluent Delfin, TL-419 and gave 9.24, 10.97 and 8.24% more ear weight respectively than under ground water.

Maximum ear weight was recorded by Delfin under both main plot treatments, An increase of 96.88 and 98.70% over HD-2204 under ground water and treated effluent respectively was noted. Delfin showed an increase of 18.76 and 34.25% over TL-419 and Driera respectively under ground water and 16.09 and 27.34% under treated effluent.

4.1.4.4 Spikelet number per ear

It is clear from Table 23 that more spikelets were produced under treated effluent conditions, being 9.17% higher under when compared with the effect of water.

Table 22. Effect of ground water and treated effluent on ear weight (g) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Main plots: Treated effluent	Mean
Delfin	12.66	13.83	13.26
TL-419	10.66	11.83	11.24
Driera	9.43	10.86	10.14
HD-2204	6.43	6.96	6.60
Mean	9.79	10.87	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.496
Sub-plot marginal means (S)	0.367
Main plot means at the same level of sub-plots (M x S)	0.519
Sub-plot means at the same level of main plot (S x M)	0.634

Table 23. Effect of ground water and treated effluent on spikelet number of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Treated effluent	Mean
Delfin	34.83	37.96	36.39
TL-419	24.23	26.56	25.39
Driera	27.53	29.90	28.71
HD-2204	17.20	18.86	18.03
Mean	25.94	28.32	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.598
Sub-plot marginal means (S)	0.641
Main plot means at the same level of sub-plots (M x S)	0.907
Sub-plot means at the same level of main plot (S x M)	0.948

Regarding the sub-plot means, maximum spikelets per ear were produced by Delfin, followed by Driera. HD-2204 produced the lowest spikelet number. Delfin showed an increase of 101.83 and 26.75% over HD-2204 and Driera respectively.

Treated effluent produced more spikelets than ground water in all varieteis. Treated effluent produced highest number of spikelet in Delfin, followed by Driera and lowest in HD-2204. Under treated effluent, these varieties gave 8.98, 8.60 and 9.65% more spikelets respectively compared to their respective counterparts.

Delfin produced significantly more spikelet number under both treatments, showing an increase of 102.50% and 101.27% over HD-2204 under ground water and treated effluent respectively. Driera proved the second best under both irrigations followed by TL-419.

4.1.4.5 Grain number per ear

It is evident from the Table 24 that treated effluent produced signifincantly more grain per ear and it was 7.39% higher compared to ground water.

Maximum grains per ear were produced by Delfin, followed by Driera. The former showed an increase of 21.90% compared to HD-2204.

Treated effluent gave more grains in all the sub-plot treatments than ground water. Treated effluent x Delfin gave an increase of 7.45% over its

Table 24. Effect of ground water and treated effluent on grain number of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Treated effluent	Mean
Delfin	53.66	57.66	55.66
TL-419	47.96	52.43	50.19
Driera	50.93	54.23	52.58
HD-2204	44.26	47.06	45.66
Mean	49.20	52.84	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	1.460
Sub-plot marginal means (S)	1.090
Main plot means at the same level of sub-plots (M x S)	1.541
Sub-plot means at the same level of main plot (S x M)	1.875

counterpart while treated effluent x HD-2204 gave an increase of 6.32% compared to ground water x HD-2204.

Delfin gave significantly more grains per ear under both treatments followed by Driera and TL-419. For example, Delfin showed an increase of 21.23 and 5.36% over HD-2204 and Driera under ground water and of 22.52% and 6.32% under treated effluent conditions. It may be pointed out here that TL-419 and Driera responded equally with treated effluent.

4.1.4.6 1,000 grain weight

It is evident from Table 25 that heavier seeds were produced under treated effluent irrigation compared with ground water application. The former gave an increase of 5.53% over the latter.

The heaviest seeds were found in HD-2204, while TL-419 showed the lowest weight among all varieties. HD-2204 showed an increase of 11.01% in 1000 grain weight when compared to Delfin. Driera and TL-419 followed the Delfin.

Under treated effluent, all the varieties gave higher values compared to their respective counterparts. The maximum value was obtained under treated effluent x HD-2204 which was 6.84% higher as compared to ground water x HD-2204 while treated effluent x Delfin gave an increase of 4.12% over ground water x Delfin.

Table 25. Effect of ground water and treated effluent on 1,000 grain weight (g) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Treated effluent	Mean
Delfin	39.31	40.93	40.12
TL-419	35.57	37.63	36.60
Driera	37.45	39.42	38.43
HD-2204	43.07	46.02	44.54
Mean	38.85	41.00	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	1.199
Sub-plot marginal means (S)	0.606
Main plot means at the same level of sub-plots (M x S)	0.858
Sub-plot means at the same level of main plot (S x M)	1.334

HD-2204 x treated effluent gave the highest 1,000 seed weight while the lowest value was recorded in TL-419 x ground water. Compared to Delfin, HD-2204 showed an increase in 1,000 seed weight by 9.56% and 12.43% under ground water and treated effluent irrigation respectively. Delfin showed an increase of 8.76 and 10.51% over TL-419 under effluent and ground water irrigation respectively.

4.1.4.7. Grain yield

Grain yield was significantly higher (7.35%) treated effluent compared to ground water (Table 26).

Considering the sub-plot means, it was observed that Delfin registered the maximum grain yield. The values given by all treatments differed critically with one another. Delfin surpassed the wheat check and gave an increase of 2.16% over HD-2204. On the other hand it recorded 20.14% more yield than TL-419.

Under treated effluent al varieties recorded significantly higher values for grain yield compared with the values obtained under ground water application. Under treated effluent application, Delfin showed an increase of 10.60% and HD-2204 of 8.98% compared to ground water conditions.

Considering the other interaction effect, it was found that Delfin with treated effluent as well as ground gave the highest grain yield, closely followed by HD-2204. The values were critically different from those for all sub-plot

Table 26. Effect of ground water and treated effluent on grain yield (q/ha) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Main plots: Treated effluent	Mean
Delfin	49.33	54.56	51.94
TL-419	42.43	44.03	43.23
Driera	43.30	45.63	44.46
HD-2204	48.66	53.03	50.84
Mean	45.93	49.31	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.503
Sub-plot marginal means (S)	0.561
Main plot means at the same level of sub-plots (M x S)	0.794
Sub-plot means at the same level of main plot (S x M)	0.819

treatments at the same level of main plot except grain yield in HD-2204 and Delfin with ground water. Delfin x treated effluent showed an increase of 2.88% over HD-2204 x treated effluent.

4.1.4.8. Straw yield

The straw yield was 2.18% more under treated effluent than under ground water application (Table 27).

Considering sub-plot means, Delfin recorded the maximum straw yield, followed by HD-2204, while TL-419 gave the lowest straw yield. The values given by all treatments differed critically with each other. Delfin gave an increase of 4.35% over HD-2204 and of 13.28% over TL-419.

Treated effluent gave significant higher values for straw yield in all varieties compared with their respective counterparts. Maximum straw yield was recorded under both treated effluent and ground water irrigations in Delfin, while the minimum value was noted in TL-419.

It was found that Delfin x treated effluent as well as Delfin x ground water out yielded other S x M interactions followed by HD-2204 under both the irrigations. Delfin showed an increase of 3.81% and 4.89% of straw production over HD-2204 under ground water and treated effluent conditions respectively.

Table 27. Effect of ground water and treated effluent on straw yield (q/ha) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Treated effluent	Mean
Delfin	130.66	135.21	132.93
TL-419	116.67	118.02	117.34
Driera	120.90	122.75	121.82
HD-2204	125.86	128.90	127.38
Mean	123.52	126.22	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	1.075
Sub-plot marginal means (S)	0.899
Main plot means at the same level of sub-plots (M x S)	1.272
Sub-plot means at the same level of main plot (S x M)	1.464

4.1.5. Grain quality

The quality characteristics (protein, carbohydrate and lysine content) were noted in grains. The salient features of the data are described here.

4.1.5.1. Protein content

The percentage of protein in the grain was significantly higher by 8.27% under ground water application as compared to treated effluent (Table 28).

Delfin recorded maximum protein content and the value was critically different from the rest of the varieties while TL-419 and HD-2204 responded equally Delfin showed an increase of 22.88% over HD-2204 while it was 22.10% over TL-419.

Ground water irrigation interacted better with giving critically different values compared to trated effluent x respective variety. Ground water and x HD-2204 ground water x Delfin showed an increase of 10.8% and 7.12% over their respective combinations of treated effluent with HD-2204 and Delfin.

Taking into account S x M interactons it was found that the grain TL-419 and HD-2204 was at par under ground water as well as treated effluetn. Delfin showed an increase of 20.84 and 25.0% over HD-2204 under ground water and treated effluent irrigations respectively.

Table 28. Effect of ground water and treated effluent on protein content (%) of triticale and wheat.

Sub-plots (Varieties)	Main plots		Mean
	Ground water	Treated effluent	
Delfin	16.23	15.15	15.69
TL-419	13.26	12.44	12.85
Driera	14.16	13.02	13.59
HD-2204	13.43	12.12	12.77
Mean	14.27	13.18	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D.at 5%
Main plot marginal means (M)	0.299
Sub-plot marginal means (S)	0.205
Main plot means at the same level of sub-plots (M x S)	0.291
Sub-plot means at the same level of main plot (S x M)	0.370

4.1.5.2. Carbohydrate content

Similar to protein content ,3.19% higher carbohydrate content was obtained with ground water than treated effluent (Table 29).

When the value of sub-plot means were compared, it was noted that Delfin contained maximum carbohydrate content while it was minimum in TL-419. The values given by Driera and HD-2204 were at par. Delfin showed an increase of 3.66% and 6.51% over HD-2204 were at par. Delfin showed an increase of 3.66% and 6.51% over HD-2204 and TL-419 respectively.

Under ground water irrigation, all the varieties showed critically different values as compared to their respective counterpart interactions. Delfin and HD-2204 showed an increase of 2.36% and 2.03% under ground water as compared to the same varieties irrigated with effluent.

While considering the S x M interactions it was noted that Delfin recorded the highest content of carbohydrate under ground water as well as treated effluent while the minimum value was given by TL-419. It was also noted that Driera and HD-2204 responded equally and gave values at par.

4.1.5.3. Lysine content

When the main plot means were taken into consideration, it was noted that similar to protein and carbohydrate, lysine content also was higher under ground water application compared to treated effluent (Table 30), the difference being 13.68%.

Table 29. Effect of ground water and treated effluent on carbohydrate content (%) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Main plots: Treated effluent	Mean
Delfin	82.16	80.26	81.21
TL-419	78.13	74.35	76.24
Driera	79.84	77.23	78.53
HD-2204	79.13	77.55	78.34
Mean	79.81	77.34	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.658
Sub-plot marginal means (S)	0.346
Main plot means at the same level of sub-plots (M x S)	0.489
Sub-plot means at the same level of main plot (S x M)	0.740

Table 30. Effect of ground water and treated effluent on lysine content (%) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Main plots: Treated effluent	Mean
Delfin	4.12	3.62	3.87
TL-419	3.11	2.76	2.93
Driera	3.36	2.90	3.13
HD-2204	2.40	2.14	2.27
Mean	3.24	2.85	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.121
Sub-plot marginal means (S)	0.141
Main plot means at the same level of sub-plots (M x S)	0.199
Sub-plot means at the same level of main plot (S x M)	0.203

All the varieties showed critically different values and Delfin gave the highest lysine content which was 70.48% and 23.64% higher than HD-2204 and Driera respectively.

Ground water showed critically different values with all the varieties as compared to their respective counterparts. Under ground water application, Delfin, HD-2204 and Driera showed an increase of 13.81, 12.14 and 15.86% when compared with their respective interactions with treated effluent.

All the values for S x M interactions were critically different, except TL-419 and Driera under treated effluent. Similar to other quality parameters, Delfin performed best and recorded the highest lysine content while HD-2204 was the poorest in terms of lysine production under ground water as well as treated effluent. Delfin recorded an increase of 71.66 and 22.61% cover HD-2204 and Driera respectively under ground water and of 69.15 and 24.82% under treated effluent application.

4.1.5.4 Protein yield

Unlike the other parameter studied, the protein yield was found to be non-significantly affected when the effect of ground water was compared with that of treated effluent (Table 31).

Delfin yielded highest protein and all varieties differed critically with each other. It recorded an increase of 25.65 and 40.41% over HD-

Table 31. Effect of ground water and treated effluent on protein yield (q/ha)of triticale and wheat.

Sub-plots (Varieties)	Main plots		Mean
	Ground water	Treated effluent	
Delfin	8.00	8.26	8.13
TL-419	5.62	5.47	5.54
Driera	6.12	5.93	5.79
HD-2204	6.53	6.42	6.47
Mean	6.56	6.52	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	N.S.
Sub-plot marginal means (S)	0.12
Main plot means at the same level of sub-plots (M x S)	0.169
Sub-plot means at the same level of main plot (S x M)	0.162

N.S. Non-significant

2204 and Driera respectively.

Under treated effluent and ground water application, Delfin and Driera showed critically different values while TL-419 and HD-2204 at par under the two treatments. Treated effluent x Delfin registered an increase of 3.25% as compared to ground water x Delfin. Driera recorded 3.20% higher protein yield under ground water compared to treated effluent.

All the varieties showed critically different values in ground water as well as treated effluent. Delfin showed an increase of 22.51 and 28.66% over HD-2204 grown with ground water and treated effluent respectively.

4.1.5.5 Carbohydrate yield

Carbohydrate yield 4.28% more with treated effluent compared to ground water (Table 32).

The four varieties showed critically different values Delfin proved best, followed by HD-2204 Driera and TL-419 in that order. The difference between Delfin and TL-419 was 27.95%.

Treated effluent gave higher carbohydrate yields in each variety except TL-419 compared to their respective ground water treated counter-parts.

All varieties showed critically different values under both treatments. Like other grain quality parameters, Delfin outyielded the other varieties and showed an increase of 5.24 and 22.23% compared to HD-2204

Table 32. Effect of ground water and treated effluent on carbohydrate yield (q/ha) of triticale and wheat.

Sub-plots (Varieties)	Main plots: Ground water	Treated effluent	Mean
Delfin	40.52	43.79	42.15
TL-419	33.15	32.73	32.94
Driera	34.56	35.39	34.97
HD-2204	38.50	41.12	39.81
Mean	36.68	38.25	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.791
Sub-plot marginal means (S)	0.412
Main plot means at the same level of sub-plots (M x S)	0.583
Sub-plot means at the same level of main plot (S x M)	0.887

and TL-419 respectively under ground water condition and of 6.49 and 23.73% respectively under treated effluent.

4.2 Experiment 2

In this split plot field experiment, the effect of two types of irrigation water (treated effluent and ground water) and five irrigation levels (I_0, I_1, I_2, I_3 and I_4) was studied on growth, yield and grain quality of triticale var Delfin. The data was mostly significant and is summarised in Tables 33 to 52.

4.2.1. Growth parameters

In addition to the usually studied growth parameters (shoot length, leaf number, tiller number fresh weight, dry weight per plant), relative water content and proline content leaves at tillering, heading and milky grain stages were studied in this experiment, in view of induced drought. The salient features of the data are described here.

4.2.1.1 Shoot length per plant

It is evident from Table 33 that treated effluent significantly increased plant height and recorded an increase of 6.24, 3.69 and 4.22% over ground water treatment at the three stages respectively.

Table 33. Effect of five levels of irrigation with ground water and treated effluent on shoot length (cm) of triticale cv. Delfin at three growth stages.

Sub-plots (Irrigation levels)	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	54.48	61.43	57.95	63.40	64.68	64.04	86.42	91.34	88.88
I_1	66.31	69.83	68.07	74.76	77.70	76.23	91.38	96.74	94.06
I_2	71.47	75.35	73.41	82.25	84.75	83.50	102.77	107.82	105.29
I_3	72.94	75.28	73.61	94.77	99.20	96.98	115.24	119.84	117.54
I_4	72.19	75.48	73.83	95.75	99.80	97.77	120.83	122.38	121.60
Mean	67.27	71.47		82.18	85.22		103.32	107.69	

N.B. A uniform basal dose ($N_{120} P_{60} K_{60}$) was applied at the time of sowing
GW - ground water; TE - Treated effluent

C.D. at 5%	T	H	M
Main plot marginal means (M)	1.564	1.029	1.665
Sub-plot marginal means (S)	0.907	0.861	0.920
Main plot means at the same level of sub- plot (MxS)	1.282	1.218	1.300
Sub- plot means at the same level of main plot(SxM)	1.824	1.422	1.911

All the sub-plot treatments gave critically different values, except I_2, I_3 and I_4 at tillering and I_3 andI_4 at heaading. I_2 and I_3 showed an increase of 26.67 and 53.37% over I_0 at tillering and heading respectively, while at the criucial milky grain stage, I_4 recorded an increase of 36.81% over I_0. At the last stage, maximum shoot length was recorded in I_4 (36.81% more than in I_0) which was closely followed by I_3.

Treated effluent gave higher values, compared with their respective counterparts at all the three successive stages under all the irrigation levels. Treated effluent x I_4 produced the tallest plants ground water x I_0, the smallest.

All the values were critically different with one another, except the values for I_2, I_3 and I_4 at tillering and I_3 and I_4 at heading under both treatments. I_4, together with treated effluent, performed best and showed an increase of 33.98% over I_0 x treated effluent, while I_4 x ground water showed an increase 39.81% over I_0 x ground water at the milky grain stage respectively. There was a linear increase in shoot length from tillering to milky grain stage.

4.2.1.2 Leaf number per plant

It is evident from Table 34 that higher leaf number was recorded under treated effluent treatment compared to ground water.

Like shoot length, all the irrigation levels gave critically different values, except I_2, I_3 and I_4 at tillering and I_3 and I_4 at heading. I_2, I_3 and

Table 34. Effect of five levels of irrigation with ground water and treated effluent on leaf number of triticale cv. Delfin at three growth stages.

Sub-plots (Irrigation levels)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	13.30	15.17	14.23	17.48	18.14	17.81	11.17	11.88	11.52
I_1	18.09	21.05	19.57	21.79	24.77	23.28	12.99	13.28	13.48
I_2	26.01	27.88	26.94	25.84	28.79	27.31	17.67	21.16	19.41
I_3	26.22	28.29	27.25	27.95	32.87	30.41	22.80	26.88	24.84
I_4	26.42	28.09	27.25	28.76	32.92	30.84	24.90	26.95	25.92
Mean	22.00	24.09		24.36	27.49		17.90	20.19	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.603	1.036	0.424
Sub-plot marginal means (S)	0.719	0.454	0.699
Main plot means at the same level of sub- plot (MxS)	1.016	0.643	0.989
Sub- plot means at the same level of main plot(SxM)	1.052	1.118	0.958

recorded an increase of 89.31, 70.74 and 125.0% over I_0 at the three successive stages of growth respectively.

Treated effluent gave significantly higher values with all the sub-plot treatments as compared to ground water except I_0 that gave equal values under both main plant treatments at milky grain stage. Treated effluent x I_4 produced maximum leaves, being 6.32, 14.46 and 8.23% more than ground water x I_4 at the three samplings.

When the other interaction (S x M) was taken into consideration, it was noted that I_2, I_3 and I_4 at tillering, I_3 and I_4 at heading interacting with ground water as well as treated effluent gave values that were at par. At milky grain stage, whereas I_3 and I_4 were equal in their effect under treated effluent treatment, the rest of the values were critically different. I_3 x treated effluent registered an increase of 81.20 and 126.26% over control (I_0) at heading and milky grain stage respectively. Leaf production increased from tillering to heading and decreased from heading to milky grain stage.

4.2.1.3 Tiller number per plant

Like the other growth parameters studied, treated effluent produced more tillers and it showed an increase of 21.48, 19.83 and 14.47% over ground water irrigation at the three successive stages of growth (Table 35).

All the values were critically different at all the three stages of growth, except I_3 and I_4 at tillering and heading I_2 closely followed I_3 at the three stages.

Table 35. **Effect of five levels of irrigation with ground water and treated effluent on tiller number of triticale cv. Delfin at three growth stages.**

Sub-plots (Irrigation levels)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	2.24	3.13	2.68	2.33	3.33	2.83	2.14	3.13	2.63
I_1	4.33	5.43	4.88	4.28	5.37	4.82	4.35	5.15	4.75
I_2	6.37	8.51	7.44	6.21	8.38	7.29	6.33	7.35	6.84
I_3	8.13	9.52	8.82	8.62	9.92	9.27	8.45	9.46	8.95
I_4	8.51	9.33	8.92	9.34	9.89	9.61	9.14	9.75	9.44
Mean	5.91	7.18		6.15	7.37		6.08	6.96	

N.B. A uniform basal dose ($N_{120}P_{60}K_{60}$) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.901	0.197	0.304
Sub-plot marginal means (S)	0.360	0.597	0.382
Main plot means at the same level of sub- plot (MxS)	0.509	0.844	0.541
Sub- plot means at the same level of main plot(SxM)	0.955	0.777	0.552

I_3 showed an increase of 229.10 and 227.56% over I_0 at the two later stages of growth. Control (I_0) gave the poorest performance at all the stages.

Treated effluent interacting with all the irrigation levels gave significantly higher values compared to the respective ground water x I' combinations at all the three stages of growth, except I_4 which gave values at par at heading. Treated effluent x I_4 showed an increase of 9.63 and 6.67% over ground water x I_4 at tillering and milky grain stage respectively.

All the interactions (S x M) except I_3 and I_4, had statistically different effect both irrigation treatments at tillering and heading while at milky grain stage, the values were at par under treated effluent only. Control (I_0) showed the poorest performance under ground water as well as treated effluent at the three stages.

4.2.1.4 Fresh weight per plant

Treated effluent gave more fresh weight compared to ground water application at all the three samplings. The former registered an increase of 12.28, 14.98 and 8.52% over ground water application at the three successive stages of growth (Table 36).

The values given by I_2, I_3 and I_4 at tillering and by I_3 and I_4 at heading and milky grain stages were at par, while all the remaining values were critically different. At tillering, I_2 proved best, showing an increase of 79.39% over I_0. However, at heading and milky grain stage, I_3 recorded an increase

Table 36. Effect of five levels of irrigation with ground water and treated effluent on fresh weight (g) of triticale cv. Delfin at three growth stages.

Sub-plots (Irrigation levels)	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	13.00	14.57	13.78	18.70	20.77	19.73	26.50	26.21	27.35
I_1	17.68	20.82	19.25	28.31	32.14	30.22	34.70	38.86	36.78
I_2	23.47	25.98	24.72	31.86	36.05	33.95	39.00	42.89	40.94
I_3	23.84	26.44	25.14	35.75	41.95	38.85	46.45	51.22	49.83
I_4	23.79	26.48	25.13	35.91	42.14	39.02	48.71	50.82	49.76
Mean	20.35	22.85		30.10	34.61		39.07	42.40	

N.B. A uniform basal dose ($N_{120}P_{60}K_{60}$) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	1.007	0.749	1.216
Sub-plot marginal means (S)	0.746	0.725	0.914
Main plot means at the same level of sub- plot (MxS)	1.081	1.026	1.293
Sub- plot means at the same level of main plot(SxM)	1.320	1.131	1.586

of 96.90 and 82.19% respectively over I_0.

Treated effluent together with all sub-plot treatments recorded more fresh weight compared to the respective combinaions with ground water, except I_0 at milky grain stage. Treated effluent x I_4 showed an increase of 11.30, 17.34 and 4.33% over ground water x I_4 at the three staages of growth respectively.

While considering the S x M interaction, it was noted that I_2, I_3 and I_4 at tillering and I_3 and I_4 at heading gave at par after values with ground water as well as treated effluent. At milky grain stage, I_4 x ground water proved best while, treated effluent, I_3 and I_4 were at par. I_3 x treated effluent showed an increase of 101.97 and 95.42% at heading and milky grain stage respectively while at tillering I_2 x treated effluent was 78.31% more effective than I_0 x treated effluent.

4.2.1.5 Dry weight per plant

Higher dry weight was recorded under treated effluent irrigation compared to ground water at all the three stages of growth. The former recorded an increase of 23.29, 23.82, and 8.7% over ground water at the three successive samplings (Table 37).

The values given by I_2, I_3 and I_4 at tillering I_3 and I_4 at heading and milky grain stages were at par, while all other values were critically different. I_3 showed an increase of 122.64 and 84.45% over I_0 (Control) at the later two

Table 37. Effect of five levels of irrigation with ground water and treated effluent on dry weight (g) of triticale cv. Delfin at three growth stages.

Sub-plots (Irrigation levels)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	2.92	3.96	3.44	4.27	5.28	4.77	12.08	12.51	12.29
I_1	4.67	5.42	5.04	6.39	7.93	7.16	15.38	17.10	16.24
I_2	6.40	8.06	7.23	7.88	9.34	8.61	17.26	18.73	17.99
I_3	6.60	7.97	7.28	9.40	11.85	10.62	21.39	23.96	22.67
I_4	6.49	7.95	7.22	9.44	11.85	10.64	22.38	23.85	23.11
Mean	5.41	6.67		7.47	9.25		17.69	19.23	

N.B. A uniform basal dose ($N_{120} P_{60} K_{60}$) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.784	1.069	0.460
Sub-plot marginal means (S)	0.416	0.355	0.977
Main plot means at the same level of sub- plot (MxS)	0.588	0.502	1.382
Sub- plot means at the same level of main plot(SxM)	0.888	1.105	1.299

stages of growth.

Treated effluent with all sub-plot treatments recorded more dry weight compared to ground water, except the value given by I_0 which was at par under both treatments at milky grain stage treatments. Treated effluent x I_4 showed an increase of 22.49, 25.52 and 6.56% over ground water x I_4 at the three samplings.

I_2, I_3 and I_4 at tillering and I_3 and I_4 at heading milky grain stages were at par in their interaction effect with ground water as well as treated effluent. I_3 x treated effluent recorded and increase of 124.43 and 91.52% over I_0 x treated effluent while I_3 x ground water registered an increase of 120.14 and 77.06% over I_0 x ground water at the later two growth stages respectively. There was linear necrease ind ry weight from tillering tomilky grain stage.

4.2.2 Proline Content

More proline was accumulated in leaves under treated effluent irrigation compared to ground water application, except at tillering where the value was non-significant (Table 38.)

All the irigation levels gave statistically different values at all the three stages of growth, except I_3 and I_4 at heading and milky grain stages. I_0 accumulated maximum proline, followed byI_1 at all the three growth staages.

Treated effluent recorded higher proline content under all the irrigation levels compared to the latter's respective combinatios with g round

Table 38. Effect of five levels of irrigation with ground water and treated effluent on proline content (mg/g fresh weight) of triticale cv. Delfin at three growth stages.

Sub-plots (Irrigation levels)	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	3.12	3.21	3.16	4.84	4.96	4.90	5.37	5.42	5.39
I_1	1.72	1.79	1.75	2.61	2.71	2.66	2.91	2.96	2.93
I_2	0.91	0.96	0.93	1.24	1.35	1.29	1.63	1.67	1.65
I_3	0.20	0.23	0.21	0.23	0.29	0.26	0.26	0.28	0.27
I_4	0.24	0.28	0.26	0.25	0.29	0.27	0.22	0.30	0.26
Mean	1.23	1.29		1.83	1.92		2.07	2.12	

N.B. A uniform basal dose ($N_{120}P_{60}K_{60}$) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	N.S	0.035	0.012
Sub-plot marginal means (S)	0.019	0.021	0.016
Main plot means at the same level of sub- plot (MxS)	0.027	0.030	0.023
Sub- plot means at the same level of main plot(SxM)	0.064	0.044	0.024

N.S. - Non - significant

water. Treated effluent x I_0 accumulated maximum proline at milky grain stage while the least proline was accumulated under the combination ground water x I_0 at tillering.

All S x M interactions gave critically different values, except in the case of I_3 and I_4 at tillering and heading. However, at milky grain s tage, I_3 and I_4 were at pave under treated effluent. At all the three stages, maximum proline accumulation occured in I_0, followed by I_1 and I_2 in both main plots. It was also noted that there was a linear decrease in proline as the irrigation level increased at all the three stages of growth.

4.2.3 Relative water content (RWC)

Like the other growth parameters, treated effluent gave higher values for RWC compared to the ground water (Table 39).

All the irrigation levels gave critically different values, except I_3 and I_4 only at tillering. The latter gave the maximum value which was closely followed by I_3 and showed an increase of 33.91 and 37.74% over the control (I_0) at the later two growth stages respectively.

All the sub-plot treatments gave higher values with treated effluent compared to their respective combinations with ground water at the three stages, except I_0 whose effect was at par under ground water as well as treated effluent at tillering. It may be noted that the values given by treated effluent were closely followed by the values recorded under ground water irrigation

Table 39. **Effect of five levels of irrigation with ground water and treated effluent on relative water content (%) of triticale cv. Delfin at three growth stages.**

Sub-plots (Irrigation levels)	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	GW	TE	Mean	GW	TE	Mean	GW	TE	Mean
I_0	67.66	68.45	68.05	63.09	65.33	64.21	59.18	61.08	59.63
I_1	76.04	77.14	76.59	73.10	74.17	73.63	67.07	69.11	68.09
I_2	84.62	86.66	85.64	80.46	81.24	80.85	75.92	77.14	76.53
I_3	86.45	88.87	87.66	84.11	86.31	85.21	80.11	83.15	81.63
I_4	86.58	88.95	87.76	85.12	86.86	85.99	81.16	83.13	82.14
Mean	80.27	82.01		77.17	78.78		72.68	74.72	

N.B. A uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing.
GW - ground water; TE - Treated effluent

C.D. at 5%	T	H	M
Main plot marginal means (M)	0.382	0.204	0.102
Sub-plot marginal means (S)	0.711	0.289	0.229
Main plot means at the same level of sub- plot (MxS)	1.006	0.408	0.325
Sub- plot means at the same level of main plot(SxM)	0.970	0.414	0.306

at each of the stages of growth.

While considering the S x M interacation it was noted that almost all the sub-plot treatments showed different values at the three stages of growth. Ground water x I_4 gave the highest values except at tillering, which were closely followed by the I_3 interactions at all the stages. On the other hand treated effluent x I_3 gave the values at par with I_4 at tillering and milky grain stages. Treated effluent x I_3 showed an increase of 29.83, and 36.13% over its control (I_0) at tillering and milky grain stages and ground water x I_4 recorded an increase of 34.91 and 37.14% over I_0 at heading and milky grain stages of growth respectively. It was also noted that there was linear decrease in RWC from tillering to milky grain stage.

4.2.4 Yield parameters

The treatment showed significant effect on yield parameters. The data are presented in Table 40 to 47 and are briefly discribed below.

4.2.4.1 Ear number per plant

Trerated effluent produced 18.64% more ears compared to ground water application (Table 40).

I_3 and I_4 gave at par after values while the rest of irrigation levels were critically different.

Table 40. Effect of five levels of irrigation with ground water and treated effluent on ear number of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Treated effluent	Mean
I_0	2.14	3.14	2.64
I_1	3.34	4.75	4.04
I_2	6.35	7.13	6.74
I_3	8.24	9.43	8.83
I_4	8.67	9.62	9.14
Mean	5.74	6.81	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.353
Sub-plot marginal means (S)	0.449
Main plot means at the same level of sub-plots (M x S)	0.634
Sub-plot means at the same level of main plot (S x M)	0.646

All the sub-plot treatments produced more ears with the treated effluent when compared to ground water application. Treated effluent produced 46.72 and 10.95% more ears than ground water application when interacting with I_0 and I_4 respectively.

I_3 and I_4 gave values that were at par with each other while the remaining values were critically different under the two irrigants. I_3 showed an increase of 200.13 and 285.04% when compared with I_0 under treated effluent and ground water respectively, while the same irrigation level I_3 showed an increase of 29.76 and 32.25% when compared with I_2 under ground water and treated effluent respectively.

4.2.4.2 Ear weight per plant

Table 41 indicates that treated effluent produced higher ear weight compared to ground water application.

I_4 proved best which showed an increase of 100.47% over I_0. I_4 was closely followed by I_3 and showed an increase of only 7.73% over I_3.

Under both irrigation waters all sub-plot treatments, except I_2 and I_3, gave at par values. Treated effluent x I_3 gave an increase of 18.88% over ground water x I_3.

I_4 x ground water proved best while I_3 x treated effluent and I_4 x treated effluent were at par with each other in their effect. I_1 and I_2 under ground water also performed similarly while all the other values under both main-plot

Table 41. Effect of five levels of irrigation with ground water and treated effluent on ear weight (g) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Treated effluent	Mean
I_0	5.90	6.74	6.32
I_1	8.94	8.86	8.90
I_2	9.56	11.22	10.39
I_3	10.75	12.78	11.76
I_4	12.81	12.53	12.67
Mean	9.59	10.42	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.322
Sub-plot marginal means (S)	0.603
Main plot means at the same level of sub-plots (M x S)	0.853
Sub-plot means at the same level of main plot (S x M)	0.813

treatments were critically different. I_3 x treated effluent showed an increase of 89.61% while different. I_3 x treated effluent showed an increase of 117.11% over I_0 x treated effluent and I_0 x ground water respectively.

4.2.4.3 Length per ear

Longer ears were produced by treated effluent irrigation than ground water treatment (Table 42).

I_4 proved best while control I_0 produced ears of shortest length. An increase of 57. 19% by I_4 over control was recorded while I_3 closely followed I_4.

Treated effluent showed higher values compared to ground water irrigation except I_0, I_1 and I_4. Like ear weight, length per ear responded similarly to sub-plot treatments I_0, I_1 andI_4 under ground water and treated effluent.

I_4 gave maximum ear length under ground water while, like ear weight, I_3 and I_4 proved at par under treated effluent irrigation. I_3 x treated effluent gave an increase of 59.13% over I_0 x treated effluent while I_4 x ground water gave an increase of 55.06% over I_0 x ground water irrigation.

4.2.4.4 Spikelet number per ear

Like the other yield attributing parameters, treated effluent produced more spikelets as compared to ground water (Table 43), the difference being 7.68%.

Table 42. Effect of five levels of irrigation with ground water and treated effluent on length per ear (cm) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	16.18	16.20	16.19
I_1	18.16	18.80	18.48
I_2	20.30	22.69	21.49
I_3	23.46	25.78	24.62
I_4	25.09	25.81	25.45
Mean	20.63	21.85	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.790
Sub-plot marginal means (S)	0.556
Main plot means at the same level of sub-plots (M x S)	0.787
Sub-plot means at the same level of main plot (S x M)	0.998

Table 43. Effect of five levels of irrigation with ground water and treated effluent on spikelet number of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	18.21	18.73	18.47
I_1	25.89	26.86	26.37
I_2	29.32	32.90	31.11
I_3	34.17	38.17	36.17
I_4	36.21	38.23	37.22
Mean	28.76	30.97	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.216
Sub-plot marginal means (S)	0.674
Main plot means at the same level of sub-plots (M x S)	0.953
Sub-plot means at the same level of main plot (S x M)	0.877

All the sub-plot treatments gave critically different values. Maximum number of spikelet was produced under I_4 which was closely followed by I_3. I_4 recorded 100.51% more spikelets than I_0.

Treated effluent with all irrigation levels, except I_0, produced more spikelets as compared to the respective combinations with ground water. Treated effluent x I_4 produced highest number of spikelets and showed an increase of 5.57% over ground water x I_4.

Maximum spikelets were produced by the treatment I_4 x ground water while I_3 and I_4 gave at par values under treated effluent. Lowest number of spikelets was recorded in I_0 under grond water as well as treated effluent.

4.2.4.5 Grain number per ear

Treated effluent proved better and gave 5.37% higher value for grain number compared to ground water (Table 44).

When sub-plot means were considered it was noted that all the values were critically different and I_4 proved best, closely followed by the I_3. The former recorded an increase of 115.75% over I_0 and 2.36% over I_3.

Treated effluent gave higher values compared ground water irrigation in all sub-plots, accept I_0. Treated effluent with I_3 and I_4 recorded an increase of 9.35 and 4.23% when compared with ground water x I_3 and ground water x I_4.

All the sub-plot treatments under both irrigation waters gave critically

Table 44. Effect of five levels of irrigation with ground water and treated effluent on grain number of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Treated effluent	Mean
I_0	25.63	26.05	25.84
I_1	36.90	37.92	37.41
I_2	44.76	47.65	46.20
I_3	52.03	56.90	54.46
I_4	54.60	56.91	55.75
Mean	42.78	45.08	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.714
Sub-plot marginal means (S)	0.576
Main plot means at the same level of sub-plots (M x S)	0.815
Sub-plot means at the same level of main plot (S x M)	0.967

different values except, I_3 and I_4 with treated effluent. The latter gave an increase of 113.03 and 4.93% over I_0 and I_3 respectively under ground water irrigation while under treated effluent I_3 showed an increase of 118.42% over I_0.

4.2.4.6 1,000 grain weight

It is evident from Table 45 that treated effluent application produced only 1.42% higher 1,000 grain weight than gound water.

I_4 proved the best irrigation level but was closely followed by I_3 and recorded an increase of 21.39% over I_0.

The effect of main plot means at the same level of sub-plot on 1,000 grain weight was non-significant.

It was noted that four irrigations (I_4) under ground water gave the highest 1,000-grain weight while the values were at par in I_3 and I_4 under treated effluent. The lowest seed weight was recorded with I_0 under both irrigants. Compared to I_0, I_4 increased 1,000 grain weight by 20.89% under ground water and I_3 increased it by 19.45% under treated effluent.

4.2.4.7 Grain yield

Like the other yield parameters, treated effluent produced 6.1% more yield compared to the ground water. (Table 46).

All the values for irrigation levels were critically different from each

Table 45. Effect of five levels of irrigation with ground water and treated effluent on 1,000 grain weight (g) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Treated effluent	Mean
I_0	32.78	33.05	32.91
I_1	34.60	34.64	34.62
I_2	36.56	37.39	36.97
I_3	38.66	39.48	39.07
I_4	39.63	40.28	39.95
Mean	36.44	36.96	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.340
Sub-plot marginal means (S)	0.649
Main plot means at the same level of sub-plots (M x S)	N.S.
Sub-plot means at the same level of main plot (S x M)	0.872

N. S. - Non-significant

Table 46. **Effect of five levels of irrigation with ground water and treated effluent on grain yield (q/ha) of triticale cv. Delfin.**

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	26.74	26.27	26.50
I_1	30.95	32.60	31.77
I_2	40.48	42.83	41.65
I_3	46.82	52.51	49.66
I_4	49.89	52.57	51.23
Mean	38.97	41.35	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.505
Sub-plot marginal means (S)	0.667
Main plot means at the same level of sub-plots (M x S)	0.943
Sub-plot means at the same level of main plot (S x M)	0.971

other. Maximum grains were produced with four irrigations, closely followed by three irrigations. The minimum grain yield was recorded in the control (I_0).

Treated effluent together with all the sub plot treatments yielded more grains compared to their respective counterparts, except I_0. Treated effluent x I_4 produced maximum grains and showed an increase of 5.37% over ground water x I_4.

The interaction of the sub-plot treatment with ground water as well as treated effluent showed critically different values except I_3 and I_4 under treated effluent. I_4 x ground water recorded maximum yield, which was followed by I_3 x ground water. On the other hand, I_3 xtreated effluent showed an increase of 99.88% over I_0 x treated effluent.

4.2.4.8 Straw yield

Treated effluent increased straw yield by 2.81% more over ground water irrigation (Table 47).

Among the various irrigation levels, I_4 gave maximum straw yield whereas I_0 produced minimum straw. The former recorded an increase of only 2.28% over I_3.

Treated effluent together with all sub-plot treatments gave higher straw as compared to their respective counterparts, except I_1 which gave values at par under both irrigation treatments. Treated effluent x I_4 produced maximum straw yield.

Table 47. Effect of five levels of irrigation with ground water and treated effluent on straw yield (q/ha) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Treated effluent	Mean
I_0	37.10	38.46	37.78
I_1	62.42	62.38	62.40
I_2	76.28	78.57	77.42
I_3	123.43	130.02	126.72
I_4	128.67	130.56	129.61
Mean	85.58	87.99	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	1.272
Sub-plot marginal means (S)	0.834
Main plot means at the same level of sub-plots (M x S)	1.179
Sub-plot means at the same level of main plot (S x M)	1.556

While considering the S x M interactions, it was noted that I_4 recorded maximum straw under ground water while, under treated effluent, I_3 proved as effective as I_4. The rest of the values were critically different from each other. I_0 under ground water as well as treated effluent showed the poorest effect.

4.2.5 Grain quality

The quality parameters (protein, carbohydrate and lysine content) were noted in grains. The salient features of the data are presented here.

4.2.5.1 Protein content (%)

Unlike the growth and yield parameters, ground water produced 6.14% more protein compared to treated effluent (Table 48).

On the other hand, like most of the growth and yield parameters, I_3 produced the maximum protein and I_0 the minimum, the former being 16.70% than the latter.

Ground water with all irrigation levels yielded more protein compared to its counterpart. Ground water x I_0 and ground water xI_3 recorded an increase of 8.03 and 7.32% respectively over treated effluent x I_0 and treated effluent x I_3

All the sub-plot treatments, supplied with ground water as well as treated effluent, gave critically different values, except I_0 and I_1. I_3 proved best in both main plots and showed an increase of 16.28 and 17.06% over I_0 under

Table 48. Effect of five levels of irrigation with ground water and treated effluent on protein (%) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	14.12	13.07	13.59
I_1	14.28	13.19	13.73
I_2	15.16	14.22	14.69
I_3	16.42	15.30	15.86
I_4	16.04	14.99	15.51
Mean	15.02	14.15	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.033
Sub-plot marginal means (S)	0.138
Main plot means at the same level of sub-plots (M x S)	0.196
Sub-plot means at the same level of main plot (S x M)	0.178

ground water and treated effluent respectively.

4.2.5.2 Carbohydrate content(%)

Like protein, carbohydrate in grains was also higher under ground water (2.44%) compared to treated effluent (Table 49).

Regarding the sub-plot means, it was observed that I_0, I_1 and I_2 were equally effective as were I_3 and I_4. I_3 recorded an increase of 3.75% in carbohydrate content over I_0.

Ground water with all the irrigation levels, including I_0, gave significantly higher carbohydrate content than the treated effluent x irrigation levels. It was also observed that the highest content of carbohydrate was the effect of ground water x I_3 interaction while lowest was under treated effluent x I_0.

While considering the S x M interaction, it was noted that, at lower levels of irrigations (I_0, I_1 and I_2 the values were at par under both irrigants. On the other hand, I_3 was as effective as I_4 and gave significantly higher value than I_0, I_1 and I_2 under both irrigants.

4.2.5.3 Lysine content (%)

Ground water significantly increase the lysine content of grain compared to treated effluent (Table 50).

Table 49. **Effect of five levels of irrigation with ground water and treated effluent on carbohydrate (%) of triticale cv. Delfin.**

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	79.29	77.42	78.35
I_1	79.62	77.75	78.68
I_2	80.38	78.31	79.34
I_3	82.24	80.35	81.29
I_4	82.12	80.18	81.15
Mean	80.73	78.80	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	1.153
Sub-plot marginal means (S)	0.707
Main plot means at the same level of sub-plots (M x S)	1.000
Sub-plot means at the same level of main plot (S x M)	1.373

Table 50. **Effect of five levels of irrigation with ground water and treated effluent on lysine content (%) of triticale cv. Delfin.**

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	3.76	3.35	3.55
I_1	3.82	3.42	3.62
I_2	3.91	3.48	3.69
I_3	4.14	3.71	3.92
I_4	4.08	3.51	3.79
Mean	3.94	3.49	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.062
Sub-plot marginal means (S)	0.070
Main plot means at the same level of sub-plots (M x S)	0.099
Sub-plot means at the same level of main plot (S x M)	0.104

At lower levels of irrigation (I_0, I_1 and I_2) the values were at par. Thehighest lysine content was found with three irrigations (I_3) which was closely followed by I_4.

Ground water with all irrigation levels showed higher values compared to treated water. The highest lysine content was noted in ground water x I_3 and was 11.59% higher than treated effluent x I_3 while ground water x I_0 registered an increase of 12.23% compared to its counterpart.

Like carbohydrate, lysine content also showed values at par under lower levels (I_0, I_1 and I_2) of irrigation under both irrigants. I_3 and I_4 again gave values at par under ground water. However, the former gave the highest lysine content under treated effluent, being 10.74% more than I_0 x treated effluent.

4.2.5.4 Protein yield

It is evident from Table 51 that ground water yielded more protein compared to treated effluent, the difference being 1.17%.

All the sub-plot means showed critically different values except I_3 and I_4. The former recorded an increase of 118.88% when compared with I_0.

Ground water as well as treated effluent responded equally and gave values at par with I_1, I_2 and I_4. However, treated effluent x I_3, proved the best M x S combination.

All the sub-plot treatments gave critically different values under

Table 51. Effect of five levels of irrigation with ground water and treated effluent on protein yield (q/ha) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Main plots: Treated effluent	Mean
I_0	3.77	3.43	3.60
I_1	4.41	4.29	4.35
I_2	6.13	6.08	6.10
I_3	7.74	8.03	7.88
I_4	8.00	7.88	7.94
Mean	6.01	5.94	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.012
Sub-plot marginal means (S)	0.110
Main plot means at the same level of sub-plots (M x S)	0.156
Sub-plot means at the same level of main plot (S x M)	0.140

ground water as well as treated effluent irrigation. Under ground water x I_4 recorded the highest protein yield and showed an increase of 112.20% over I_0. On the other hand I_3 x treated effluent gave the highest yield of protein and showed an increase of 134.11% over I_0 x treated effluent.

4.2.5.5 Carbohydrate yield

Unlike the protein yield, treated effluent yielded 3.38% more carbohydrate than ground water (Table 52).

Among the various irrigations levels, I_4 proved the best and showed an increase of 100.14 and 2.92% over I_0 and I_3 respectively.

Treated effluent with all irrigation levels except I_0 and I_1 more carbohydrate as compared to ground water. Both treated effluent and ground water interacted with I_4 to record the maximum carbohydrate yield .

All the sub-plot treatments under ground water as well as treated effluent gave critically different values except I_3 and I_4 under treated effluent. I_3 x treated effluent recorded maximum value and its carbohydrate yield was 106.83% more than that of I_0 x treated effluent.

4.3 Experiment 3

In this split-plot field trial on triticale variety Delfin, cultivated under treated effluent irrigation, the effect of three levels of potassium (main plot treatments) and four levels of irrigation (sub-plot treatments) was studied

Table 52. Effect of five levels of irrigation with ground water and treated effluent on carbohydrate yield (q/ha) of triticale cv. Delfin.

Sub-plots (Irrigation levels)	Main plots: Ground water	Treated effluent	Mean
I_0	21.19	20.35	20.77
I_1	24.64	25.34	24.99
I_2	32.53	33.53	33.03
I_3	38.69	42.09	40.39
I_4	40.97	42.17	41.57
Mean	31.60	32.67	

N.B. Uniform basal dose (N_{120} P_{60} K_{60}) was applied at the time of sowing

	C.D. at 5%
Main plot marginal means (M)	0.340
Sub-plot marginal means (S)	0.545
Main plot means at the same level of sub-plots (M x S)	0.770
Sub-plot means at the same level of main plot (S x M)	0.750

taking into account the growth, leaf proline and relative water content (RWC) yield and quality parameters (Tables 53 to 70).

4.3.1 Growth parameters

The growth parameters were studied at tillering, heading and milky grain stages and the data were found to be significant (Table 53 to 59). Interestingly, all the growth parameters were equally affected at tillering and heading under I_2 and I_3. The data for various growth parameters as affected by treatments are described here briefly.

4.3.1.1 Shoot length per plant

The treatment K_{60} gave taller plants as compared to K_0 and K_{30} and it showed an increase of 10.11, 9.06 and 8.82% over K_0 at the three growth stages respectively (Table 53).

At tillering and heading, I_3 and I_2 were at par while, at milky grain stage, I_3 was best. I_2 recorded an increase of 19.86 and 29.32% at tillering and heading respectively while I_3 showed an increase of 31.96% at milky grain stage over I_0.

K_{60} produced more shoot length compared to K_0 and K_{30} at all the three stages under all the irrigation regimes. It was also noted that maximum shoot length was given by K_{60} x I_3 which showed an increase of 10.52, 10.12 and 9.21% over K_0 x I_3 at the three successive stages.

Table 53. **Effect of three levels of potassium and four levels of irrigation and of their interaction on shoot length (cm) of triticale cv. Delfin cultivated with treated effluent at three stages of growth.**

Sub-plots (Irrigation levels)	Stages of sampling											
	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	57.82	60.62	62.93	60.45	60.65	63.86	65.71	63.40	83.80	87.75	90.71	87.42
I_1	62.85	65.79	69.43	66.02	72.10	74.97	77.70	74.92	87.88	92.55	96.03	92.15
I_2	68.67	72.84	75.89	72.46	78.21	81.92	85.85	81.99	96.84	101.35	105.05	101.08
I_3	68.78	73.03	76.02	72.61	78.13	81.90	86.04	82.02	110.74	114.39	120.95	115.36
Mean	64.53	68.07	71.06		72.27	75.66	78.82		94.81	99.01	103.18	

N.B. A uniform three irrigations were given during the experiment.

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.730	0.886	0.777
Sub-plot marginal means (S)	0.519	0.443	0.671
Main plot means at the same level of sub- plot (MxS)	0.899	0.768	1.163
Sub- plot means at the same level of main plot(SxM)	1.058	1.097	1.261

I_2 together with K_0, K_{30} and K_{60} recorded an increase of 18.76, 20.15 and 20.59% over I_0 at tillering while the same sub-plot treatment together with K_0, K_{30} and K_{60} recorded an increase of 28.95, 28.28 and 30.64% 28.64% over I_0 *respectively at heading stage. At milky grain stage,* I_3 *proved best and* showed an increase of 32.14, 30.35 and 33.33% over I_0 with K_0, K_{30} and K_{60} respectively. It was also noted that there was a linear increase in shoot length from tillering to milky grain stage.

4.3.1.2 Leaf number per plant

It was evident from Table 55 that K_{60} produced more leaves compared to K_0 and K_{30}, except at heading where K_0 and K_{30} were equally effective.

Leaf production was more pronounced upto I_2 level. I_3 was equaled by it at tillering and heading stages. However, at milky grain stage, linear increase was noted. I_2 recorded an increase of 76.00 and 80.17% over control (I_0) at the first two samplings respectively, while, at milky grain stage, I_3 registered an increase of 135.19% over I_0.

Under K_{60} most of the sub-plot treatments produced more leaves compared to K_0 and K_{30}. The values given by K_0, and K_{30} with I_2 and I_3 were at par at heading stage while, at the last stage, they were critically different. K_{60} x I_3 recorded an increase of 26.89, 7.70 and 39.79% over K_0 x I_3 at the three stages of growth.

Incidently, I_2 and I_2 were equally effective under the various

Table 55. **Effect of three levels of potassium and four levels of irrigation and of their interaction on leaf number of triticale cv. Delfin cultivated with treated effluent at three stages of growth.**

Sub-plots (Irrigation levels)	Stages of sampling											
	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	12.86	14.84	16.55	14.75	13.84	15.77	17.46	15.69	7.87	10.99	11.77	10.20
I_1	15.76	18.84	21.65	18.75	21.84	22.91	26.03	23.59	10.81	12.56	13.93	12.43
I_2	22.65	26.32	28.91	25.96	27.62	27.51	29.70	28.27	13.51	18.37	21.76	17.88
I_3	22.83	26.48	28.97	26.09	27.77	27.84	29.91	28.50	19.80	24.51	27.68	23.99
Mean	18.52	21.62	24.02		22.76	23.50	25.77		12.99	16.60	18.78	

N.B. A uniform three irrigations were given during the experiment.

C.D. at 5%	T	H	M
Main plot marginal means (M)	0.422	0.807	0.471
Sub-plot marginal means (S)	0.524	0.401	0.555
Main plot means at the same level of sub- plot (MxS)	0.908	0.695	0.962
Sub- plot means at the same level of main plot(SxM)	0.887	0.997	0.951

potassium levels at early stages. All the other values were critically different with each other. I_2 together with K_0, K_{30} and K_{60} recorded an increase of 76.12, 77.35 and 74.68% over I_0 at tillering and of 99.59, 74.44 and 70.1% at heading stage. At milky grain stage I_3 recorded an increase of 151.58, 123.02 and 135.78% over I_0 interacting with K_0,K_{30},K_{60} respectively It was also noted that there was an increase in leaf number from tillering to heading and decrease from heading to milky grain stage.

4.3.1.3 Tiller number per plant

Like the other growth parameters, K_{60} produced significantly more tiller compared to K_0 and K_{30}. It recorded an icrease of 38.48, 88.88 and 59.01% over K_0 at the three successive growth stages (Table 54).

All the treatments gave critically different values, except I_2 and I_3 which gave at par values at tillering and heading stages like leaf number. Control (I_0) showed the poorest performance. I_2 recorded an increase of 129.89 and 132.72% when compared with I_0 at tillering and heading stages of growth respectively. However, I_3 registered an increase of 184.89% over I_0 at milky grain stage.

K_{60} produced more tillers with all the sub-plot treatments compared to other doses of potassium, except the combination of K_{30} and I_0, at all the three stages of growth. K_{60} x I_3 gave the maximum tillers at tillering, heading and milky grain stage of growth and showed an increase of 40.33, 85.58 and 50.71%

Table 54. Effect of three levels of potassium and four levels of irrigation and of their interaction on tiller number of triticale cv. Delfin cultivated with treated effluent at three stages of growth.

Sub-plots (Irrigation levels)	Stages of sampling											
	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	2.40	3.00	3.05	2.81	1.89	3.05	3.33	2.75	2.06	3.15	3.13	2.78
I_1	3.09	3.62	4.40	3.70	2.33	3.51	4.92	3.58	3.34	4.51	5.51	4.45
I_2	5.42	6.41	7.55	6.46	4.38	6.70	8.14	6.40	4.50	6.33	7.61	6.14
I_3	5.43	6.41	7.62	6.48	4.37	6.54	8.11	6.34	6.33	7.91	9.54	7.92
Mean	4.08	4.86	5.65		3.24	4.95	6.12		4.05	5.47	6.44	

N.B. A uniform three irrigations were given during the experiment.

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.215	0.264	0.296
Sub-plot marginal means (S)	0.282	0.254	0.247
Main plot means at the same level of sub- plot (MxS)	0.489	0.440	0.428
Sub- plot means at the same level of main plot(SxM)	0.473	0.460	0.470

over K_0 x I_3.

At early stages of growth (tillering and heading), I_2 and I_3 performed similarly under K_0, K_{30} and K_{60} like shoot length and leaf number. The I_0 gave the poorest performance with each k level. I_2showed an increase of 125.83, 113.60 and 147.54% when compared with I_0 with K_0, K_{30} and K_{60} at tillering. Mamimum number of tillers were reported in the combination I_3 x K_{60} at milky grain stage.

4.3.1.4 Fresh weight per plant

It is evident from Table 56 that K_{60} gave more fresh weight as compared to other treatments of potassium. It showed an increase of 23.63, 19.88 and 20.32% over I_0 at the three stages of growth.

All the sub-plot treatments gave critically different values, except I_2 and I_3 at tillering and heading. The control (I_0) showed the poorest response. I_2 showed an increase of 70.64 and 77.01% over I_0 at tillering and heading stages of growth. Maximum fresh weight was noted under I_3 at milky grain stage. Which showed an increase of 78.58% over I_0.

K_{60} with all the irrigation levels recorded maximum fresh weight compared to other doses of potassium except at tillering where K_{60} x I_0 was at par with K_{30} x I_0. K_{60} x I_3 gave the maximum fresh weight, followed K_{30} x I_3 at milky grain and an increase of 21.53% was recorded in K_{60} x I_3 over K_0 x I_3.

Table 56. **Effect of three levels of potassium and four levels of irrigation and of their interaction on fresh weight (g) of triticale cv. Delfin cultivated with treated effluent at three stages of growth.**

Sub-plots (Irrigation levels)	Stages of sampling											
	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	12.86	14.71	15.67	14.41	17.72	19.94	22.17	19.93	23.90	25.67	27.77	25.78
I_1	16.61	18.71	21.82	19.04	26.87	29.53	32.73	29.71	32.84	36.93	39.23	36.33
I_2	21.95	24.90	26.94	24.59	32.10	35.93	37.82	35.28	34.99	38.86	42.87	38.90
I_3	22.03	25.13	26.40	24.52	32.14	36.00	37.73	35.29	41.70	45.74	50.68	46.04
Mean	18.36	20.86	22.70		27.20	30.35	32.61		33.35	36.80	40.13	

N.B. A uniform three irrigations were given during the experiment.

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.412	0.356	0.465
Sub-plot marginal means (S)	0.595	0.563	0.662
Main plot means at the same level of sub- plot (MxS)	1.030	0.976	1.147
Sub- plot means at the same level of main plot(SxM)	1.978	0.913	1.092

Like the other growth parameters, fresh weight in I_2 and I_3 under all potassium levels gave at par values at tillering and heading stages. On the other hand, all other interaction values were critically different. I_0 x K_0 showed the poorest effect at each stage.

4.3.1.5 Dry Weight per plant

With regard to main plots, higher dry weight was observed under K_{60} at all the three stages compared to other doeses of potassium. It showed an increase of 71.95, 24.66 and 62.65% over K_0 (Table 57).

It was found that I_3 gave the maximum dry weight at milky grain stage. However, the values given by I_3 and I_2 were at par at tillering and heading stages. The control (I_0) showed the poorest effect. I_2 recorded an increase of 77.09 and 94.78% when compared with I_0 at tillering and heading stages respectively. I_3 recorded an increase of 74.70% over I_0 at milky grain stage.

Under K_{60} all the irrigation levels gave higher values compared with other levels of potassium. However, all potassium doses gave at par values with I_0 at tillering. K_0 x I_2 and K_{30} x I_2 and K_0 x I_3 and K_{30} x I_3 were also at par at tillering. The interaction K_{60} x I_3 gave 20.15, 20.29 and 27.54% more dry weight compared with K_0 x I_3 at the three successive stages of growth.

All the irrigation levels gave more dry weight under all the potassium levels at all the growth stages compared to their respective controls. However, like the other growth parameters, here also I_2 and I_3 were at par

Table 57. Effect of three levels of potassium and four levels of irrigation and of their interaction on dry weight (g) of triticale cv. Delfin cultivated with treated effluent at three stages of growth.

Sub-plots (Irrigation levels)	Stages of sampling											
	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	3.50	3.96	4.34	3.93	4.91	5.78	6.58	5.75	11.36	11.97	12.86	12.06
I_1	3.97	5.47	6.38	5.27	7.60	8.89	9.86	8.78	14.01	15.84	17.40	15.75
I_2	6.59	6.33	7.98	6.96	10.10	11.31	12.20	11.20	15.72	16.48	18.83	17.01
I_3	6.65	6.32	7.99	6.98	10.15	11.35	12.21	11.23	18.37	21.43	23.43	21.07
Mean	5.17	5.52	8.89		8.19	9.33	10.21		14.86	21.90	24.17	

N.B. A uniform three irrigations were given during the experiment.

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.374	0.192	0.267
Sub-plot marginal means (S)	0.297	0.297	0.297
Main plot means at the same level of sub- plot (MxS)	0.514	0.515	0.514
Sub- plot means at the same level of main plot(SxM)	0.576	0.484	0.516

under all the three main plots at tillering and heading stages. $I_2 \times K_{60}$ showed an increase of 83.87 and 85.41% over $I_0 \times K_{60}$ at tillering and heading stages of growth respectively. $I_3 \times K_{60}$ registered an increase of 82.19% over $I_0 \times K_{60}$ at milky grain stage. Like fresh weight, dry weight also increased progressively from tillering to milky grain stage.

4.3.2 Relative water content

It is evident from Table 58 that relative water content (RWC) was more under K_{60} as compared to other treatments of potassium.

On comparing the sub-plot means, it was noted that relative water content was more pronounced with I_3 at heading and milky grain stages while, at tillering, I_2 and I_3 gave at par values. I_3 recorded an increase of 29.23 and 34.69% over I_0 at the two later stages of growth.

It was noted that K_{60} interacted with all the irrigation levels to give higher values compared with other doses of potassium, except $K_{30} \times I_0$ which proved at par with $K_{60} \times I_{03}$ at tillering. For example, $K_0 \times I_3$ gave 16.53, 34.38 and 46.11% more relative water content compared with $K_0 \times I_3$ at the three stages of growth. It was noted that RWC increased with the increase in the potassium.

All the irrigation levels gave more relative water content at all the stages of growth under all the levels of potassium compared to their respective counterparts. Like the growth parameters, I_2 and I_3 gave at par values under

Table 58. **Effect of three levels of potassium and four levels of irrigation and of their interaction on relative water content (%) of triticale cv. Delfin cultivated with treated effluent at three stages of growth.**

Sub-plots (Irrigation levels)	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	62.11	67.45	68.12	65.89	53.66	64.29	65.76	61.23	47.08	60.09	61.17	56.11
I_1	70.34	75.89	78.20	74.81	64.10	72.11	76.18	70.79	57.09	66.17	68.73	63.99
I_2	72.41	78.82	88.12	79.78	68.11	78.23	84.11	76.81	64.44	71.64	80.15	72.07
I_3	72.38	78.75	88.71	79.94	72.11	78.31	86.99	79.13	68.79	74.10	83.85	75.58
Mean	69.31	75.22	80.78		64.49	73.23	78.26		59.35	68.00	73.47	

Stages of sampling: Tillering (T), Heading (H), Milky grain (M)

N.B. A uniform three irrigations were given during the experiment.

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.340	0.526	0.317
Sub-plot marginal means (S)	0.577	0.297	0.351
Main plot means at the same level of sub- plot (MxS)	1.000	0.515	0.608
Sub- plot means at the same level of main plot(SxM)	0.927	0.683	0.611

all the three main plots at tillering, while, at heading, I_2 and I_3 were equal under K_{30}. $I_3 \times K_{60}$ showed an increase of 30.22, 32.28 and 37.07% over $I_0 \times K_{60}$ at the successive stages of growth. There was a linear decrease in RWC from tillering to milky grain stage. It was also noted that RWC increased with the increase in the irrigation level under all doses of potassium.

4.3.3 Proline content

For proline content in leaves, K_{60} proved best and showed an increase of 11.42, 16.5 and 18.55% over K_0 at the three samplings (Table 59).

All the sub-plot treatments gave critically different values at all the three stages of growth. There was linear decrease in proline content with increase in irrigation level.

The potassium treatment K_{60} with all the irrigation levels recorded the maximum proline content compared to other doses at various stages of growth. However $K_{30} \times I_3$ and $K_{60} \times I_3$ gave at par values. It was further noted that proline content increased with the increase in potassium level under all the levels of irrigation. More proline content were noted at all the growth stages under all the three doses of potassium compared to their respective counter-parts. $I_0 \times K_{60}$ gave the maximum proline content at milky grain stage while $I_3 \times K_0$ at tillering gave the minimum value.

Table 59. **Effect of three levels of potassium and four levels of irrigation and of their interaction on proline content (mg/g) of triticale cv. Delfin cultivated with treated effluent at three stages of growth.**

Sub-plots (Irrigation levels)	Stages of sampling											
	Tillering (T)				Heading (H)				Milky grain (M)			
	Main plots											
	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean	K_0	K_{30}	K_{60}	Mean
I_0	3.04	3.16	3.23	3.14	4.65	4.93	4.97	4.85	5.11	5.38	5.43	5.30
I_1	1.54	1.73	1.79	1.68	2.09	2.63	2.73	2.48	2.23	2.93	2.99	2.71
I_2	0.86	0.88	0.96	0.90	1.06	1.29	1.35	1.23	1.24	1.67	1.74	1.55
I_3	0.18	0.24	0.27	0.23	0.20	0.26	0.30	0.25	0.27	0.33	0.33	0.31
Mean	1.40	1.50	1.56		2.00	2.27	2.33		2.21	2.57	2.62	

N.B. A uniform three irrigations were given during the experiment.

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.029	0.016	0.031
Sub-plot marginal means (S)	0.015	0.018	0.016
Main plot means at the same level of sub- plot (MxS)	0.025	0.032	0.027
Sub- plot means at the same level of main plot(SxM)	0.036	0.031	0.038

4.3.4 Yield parameters

The treatments showed significant effect on yield parameters. The data are briefly described below.

4.3.4.1 Ear number per plant

Ear number was more under K_{60} compared to other doses of potassium (Table 60). It may be noted that the increase from K_0 to K_{30} 35.49% was more than the increase from K_{30} to K_{60} 12.04 (%).

All the sub-plot treatments gave critically different values. I_3 produced the maximum number of ears, followed by I_2 and I_1 in that order. I_3 recorded an increase of 177.69% when compared with I_0.

At lower levels of irrigation (I_0 and I_1), K_{60} gave values that were at par with those for K_{30} while other values were critically different. The interaction K_{60} x I_3 gave the maximum ears and showed an increase of 37.29% over K_0 x I_3 while K_{60} x I_2 was 19.29% better than K_{30} x I_2.

It was noted that all S x M interactions had critically different effect and increase in irrigation number increased ear numbers at all the potassium levels. I_0 x K_0 was the poorest while I_3 x K_{60} was the most effective in this respect.

4.3.4.2 Length per ear

Like the other yield attributing parameters, maximum ear length was

Table 60. Effect of three levels of potassium and four levels of irrigation and of their interaction on ear number of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	2.00	2.94	3.13	2.69
I_1	2.92	4.13	4.35	3.80
I_2	4.30	6.22	7.42	5.98
I_3	6.22	7.66	8.54	7.47
Mean	3.86	5.23	5.86	

N.B. A uniform three irrigations were given during the expriment

	C.D. at 5%
Main plot marginal means (M)	0.371
Sub-plot marginal means (S)	0.271
Main plot means at the same level of sub-plots (M x S)	0.470
Sub-plot means at the same level of main plot (S x M)	0.546

recorded under K_{60} giving an increase of 23.07% over K_0. Again, the difference in increase from K_0 to K_{30} was more than the difference between K_{30} and K_{60} (Table 61).

All the values for sub-plot treatments were critically different. I_3 produced the longest ears, followed by I_2, I_1 and I_0 in that order. I_3 showed an increased of 47.24% over I_0.

K_{30} and K_{60} were at par and showed more ear length than K_0 at all irrigation level. Increase in potassium doses linearly increase the ear length under each irrigation level.

While considering the S x M interactions, it was noted that maximum ear length was recorded in $I_3 \times K_{60}$ and all the values were critically different. An increase of 37.40, 46.98 and 55.88% were recorded due to $I_3 \times K_0$, $I_3 \times K_{30}$ and $I_3 \times K_{60}$ when compared with $I_0 \times K_0$, $I_0 \times K_{30}$ and $I_0 \times K_{60}$ respectively.

4.3.4.3 Ear weight

It is evident from Table 62 that K_{60} produced the heaviest ears being 40.10% more than K_0.

The treatment I_3, that gave highest value for this parameter, showed an increase of 97.40% when compared with I_0.

It was revealed that the interactions $K_{60} \times I_0$, $K_{60} \times I_1$, $K_{60} \times I_2$ and $K_{60} \times I_3$ gave higher values than the interaction K_0 and K_{30} with all irrigation levels. The maximum value was obtained in the $K_{60} \times I_3$ and the minimum

Table 61. Effect of three levels of potassium and four levels of irrigation and of their interaction on length per ear of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	14.89	16.90	17.25	16.34
I_1	16.59	17.90	18.87	17.78
I_2	18.63	21.92	23.84	21.46
I_3	20.46	24.84	26.89	24.06
Mean	17.64	20.39	21.71	

N.B. A uniform three irrigations were given during the expriment

	C.D. at 5%
Main plot marginal means (M)	0.367
Sub-plot marginal means (S)	0.501
Main plot means at the same level of sub-plots (M x S)	0.868
Sub-plot means at the same level of main plot (S x M)	0.832

Table 62. **Effect of three levels of potassium and four levels of irrigation and of their interaction on ear weight (g) of triticale cv.Delfin cultivated with treated effluent.**

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	*Mean*
I_0	4.62	5.82	6.89	5.77
I_1	6.34	8.12	9.56	8.00
I_2	8.80	10.69	11.96	10.48
I_3	9.56	11.92	12.70	11.39
Mean	7.33	9.13	10.27	

N.B. A uniform three irrigations were given during the expriment

	C.D. at 5%
Main plot marginal means (M)	0.361
Sub-plot marginal means (S)	0.383
Main plot means at the same level of sub-plots (M x S)	0.664
Sub-plot means at the same level of main plot (S x M)	0.675

in K_0 x I_0.

I_3 x K_0, I_3 x K_{30} and I_3 x K_{60} proved the best combinations when compared to other combinations of sub-plot with main plots. It may be noted that I_2 x K_{60} was at par with I_3 x K_{30} showing low water requirement under higher potassium doses.

4.3.4.4 Spikelet number per ear

More spikelets were observed under K_{60}, compared to the other potassium treatments (Table 63).

Spikelets were almost doubled in I_3 when compared with I_0 and the increase was linear. I_3 registered an increase of 110.53% compared to I_0.

The effect of all the combinations of sub-plot and main plot treatments, were critically different from one another. The maximum value was obtained in the interaction K_{60} x I_3, followed by K_{30} x I_3.

It was noted that the interaction effect of S x M was distinct and all the values were critically different. I_3 combination with main plots produced more spikelets as compared to other sub-plot treatments. The lowest number of spikelets was recorded in I_0 under all potassium levels.

4.3.4.5 Grain number per ear

Like the other yield attributing parameters mentioned so far, K_{60} produced more grains as compared to K_0 and K_{30}, and it showed an increase of

Table 63. Effect of three levels of potassium and four levels of irrigation and of their interaction on spikelet number of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	15.56	16.84	18.84	17.08
I_1	24.84	26.64	27.68	26.38
I_2	28.89	30.84	33.68	31.13
I_3	32.55	36.55	38.79	35.96
Mean	25.46	27.71	29.74	

N.B. A uniform three irrigations were given during the expriment

	C.D. at 5%
Main plot marginal means (M)	0.640
Sub-plot marginal means (S)	0.491
Main plot means at the same level of sub-plots (M x S)	0.851
Sub-plot means at the same level of main plot (S x M)	0.967

20.63% over K_0 (Table 64).

I_3 produced maximum number of grains, followed by I_2. The control (I_0) produced the lowest number of grains. I_3 showed an increase of 101.78% compared to I_0.

It was noted that K_{60} produced more grains with all the sub-plot treatments and the values were critically different. Grain number was maxmum in the interaction K_{60} x I_3, followed by K_{30} x I_3.

I_3 produced more grains as compared to the other sub-plots under all the main plots. I_0 with all potassium doses produced lowest number of grains per ear.

4.3.4.6 1,000 grain weight

Heavier grains were produced under K_{60} compared with other levels of potassium (Table 65).

Consistent increase in 1,000 grain weight was noted with increase in irrigation levels. I_3 recorded an increase of 22.30% over I_0.

K_{60} interactioned best with all the sub-plot treatments with regard to 1,000 grain weight. The maximum value was recorded for the interaction K_{60} x I_3 and it was 14.81% more than the value recorded for K_0 x I_3.

I_3 produced heaviest seeds under each main plot treatment (K_0, K_{30} as well as K_{60}). The interaction I_3 x K_{60} increased this parameter by 20.54% compared with I_0 x K_{60}.

Table 64. Effect of three levels of potassium and four levels of irrigation and of their interaction on grain number of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	23.70	24.74	27.06	25.16
I_1	32.71	35.70	36.96	35.12
I_2	37.53	41.76	47.83	42.37
I_3	45.84	49.73	56.75	50.77
Mean	34.94	37.98	42.15	

N.B. A uniform three irrigations were given during the expriment

	C.D. at 5%
Main plot marginal means (M)	0.282
Sub-plot marginal means (S)	0.464
Main plot means at the same level of sub-plots (M x S)	0.803
Sub-plot means at the same level of main plot (S x M)	0.747

Table 65. Effect of three levels of potassium and four levels of irrigation and of their interaction on 1,000 grain weight (g) of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	28.64	31.57	33.82	31.34
I_1	30.67	33.99	35.78	33.48
I_2	32.81	35.86	37.87	35.51
I_3	35.51	38.71	40.77	38.33
Mean	31.90	35.03	37.06	

N.B. A uniform three irrigations were given during the expriment

	C.D. at 5%
Main plot marginal means (M)	0.768
Sub-plot marginal means (S)	0.315
Main plot means at the same level of sub-plots (M x S)	0.546
Sub-plot means at the same level of main plot (S x M)	0.894

4.3.4.7 Grain yield

Like the other attributes, potassium application was noted to give increased grain yield. K_{60} showed an increase of 36.05% over K_0 (Table 66).

I_3 yielded most, followed by I_2, I_1 and I_0 in that order. I_3 showed an increase of 100.47% when compared with I_0 and of 26.67% when compared with I_2.

K_{60} gave higher values for grain yield under all the sub-plot treatments compared with the interaction effects shown by other treatments of potassium. Maximum value was recorded for $K_{60} \times I_3$ which recorded an increase of 38.11% over $K_0 \times I_3$.

Maximum grain yield was noted in the treatment I_3 under K_{60} as well as under K_{30} and K_0. $I_0 \times K_0$ showed the lowest value.

4.3.4.8 Straw yield

It is evident from Table 67 that main plot treatment K_{60} gave higher straw yield than K_0 and K_{30}.

The higher the irrigation level the more the straw produced. I_3 gave the highest value for straw yield and showed an increase of 104.34% compared to I_0.

Higher straw yield was noted in K_{60} in all the sub-plot treatments compared with the respective interaction effects of other treatments of potassium. The interaction $K_{60} \times I_3$ yielded maximum straw and recorded an

Table 66. **Effect of three levels of potassium and four levels of irrigation and of their interaction on grain yield (q/ha) of triticale cv.Delfin cultivated with treated effluent.**

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	19.37	23.81	25.99	23.05
I_1	25.02	28.76	32.64	28.80
I_2	30.30	36.96	42.18	36.48
I_3	37.62	49.05	51.96	46.21
Mean	28.07	34.64	38.19	

N.B. A uniform three irrigations were given during the expriment.

	C.D. at 5%
Main plot marginal means (M)	0.640
Sub-plot marginal means (S)	0.619
Main plot means at the same level of sub-plots (M x S)	1.073
Sub-plot means at the same level of main plot (S x M)	1.120

Table 67. Effect of three levels of potassium and four levels of irrigation and of their interaction on straw yield (q/ha) of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	49.31	51.91	60.40	53.87
I_1	56.72	66.76	78.53	67.31
I_2	71.30	81.56	91.64	81.50
I_3	90.68	109.38	130.19	110.08
Mean	67.00	77.40	90.19	

N.B. A uniform three irrigations were given during the expriment.

	C.D. at 5%
Main plot marginal means (M)	0.983
Sub-plot marginal means (S)	0.812
Main plot means at the same level of sub-plots (M x S)	1.407
Sub-plot means at the same level of main plot (S x M)	1.552

increase of 43.57% over K_0 x I_3.

It was noted that the treatment I_3 produced highest straw yield with all the treatments of potassium and its values critically differed from the other comparable interactions. I_0 x K_0 recorded the lowest straw yield. I_3 x K_{60} showed an increase of 115.54% than I_0 x K_{60} while I_3 x K_0 showed an increase of 83.89% over I_0 x K_0.

4.3.5 Grain quality

It is revealed from Tables 63 -65 that the pattern of grain quality was comparatively different from the growth and yield parameters.

4.3.5.1 Protein content

Maximum protein was obtained under K_{60}, followed by K_{30} and the former showed an increase of 1.88% over K_0 (Table 68).

The protein content was not affected when only one irrigation was applied. However, two and three irrigations were distinct in their effect the latter being the best among all giving 15.91% more protein than I_0.

Protein was noted affected by potassium levels particularly under I_0, I_1 and I_2. On the other hand marginal increase was noted when K_{30} was applied under I_3.

While considering the S x M interactions, all values were at par except the values for I_2 and I_3 under K_{30} and K_{60}. Maximum protein was obtained

Table 68. Effect of three levels of potassium and four levels of irrigation and of their interaction on protein content (%) of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	12.82	12.95	13.05	12.94
I_1	12.86	13.05	13.12	13.01
I_2	14.68	14.76	14.91	14.78
I_3	14.83	15.05	15.12	15.00
Mean	13.79	13.95	14.05	

N.B. A uniform three irrigations were given during the expriment.

	C.D. at 5%
Main plot marginal means (M)	0.050
Sub-plot marginal means (S)	0.116
Main plot means at the same level of sub-plots (M x S)	0.202
Sub-plot means at the same level of main plot (S x M)	0.181

under I_3 x K_{30}.

4.3.5.2 Carbohydrate content

Like protein, K_{60} yielded maximum carbohydrate, followed by K_{30} and it showed an increase of 3.70% over K_0 which gave the lowest carbohydrate content (Table 69).

No irrigation and low irrigation (I_1) gave the at par values while the effects of higher irrigation levels (I_2 and I_3) were critically different and I_3 produced the maximum carbohydrate.

Unlike protein, the pattern in carbohydrate content was comparatively distinct. A consistent increase was recorded from K_0 to K_{60} interacting with I_0 to I_3. Thus, K_{60} x I_3 yielded the maximum carbohydrate and showed an increase of 5.18% over K_0 x I_3 and of 6.64% over K_0 x I_0.

On the other hand, like protein, lower levels of irrigation (I_0, I_1) were equally effective with all the doses of potassium. While at higher levels of irrigations (I_2 and I_3), statistically different values were obtained. It was noted that the increase of irrigation level interacted with increasing potassium doses, to give a linear increase in carbohydrate content.

4.3.5.3 Lysine content

Unlike protein and carbohydrate, K_0 (control) gave the highest content of lysine followed by K_{30} and K_{60}, in that order. However, the difference was

Table 69. **Effect of three levels of potassium and four levels of irrigation and of their interaction on carbohydrate content (%) of triticale cv.Delfin cultivated with treated effluent.**

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	75.12	76.54	77.46	76.37
I_1	75.34	76.88	77.82	76.68
I_2	76.95	77.66	79.42	78.01
I_3	76.16	79.56	80.11	78.61
Mean	75.89	77.66	78.70	

N.B. A uniform three irrigations were given during the expriment.

	C.D. at 5%
Main plot marginal means (M)	0.309
Sub-plot marginal means (S)	0.336
Main plot means at the same level of sub-plots (M x S)	0.583
Sub-plot means at the same level of main plot (S x M)	0.588

marginal (Table 70).

All the sub-plot treatments gave different values and maximum content of lysine was noted with three irrigations (I_3) which showed an increase of 8.08% over the control (I_0).

On comparing the values of main plot means at the same level of sub-plot it was noted that all the interaction effects were non-significant.

All the sub-plot treatments under all levels of potassium gave critically different values, except I_2 and I_3 under K_0. Unlike the other quality parameters, various irrigation level interacted with K_0 to give higher lysine content while I_3 was at par with I_2 under K_0. It was also noted that with the increase in irrigation level there was a linear increase in lysine content at each level of potassium dose.

4.4 Experiment 4

This split-plot field trial involved four doses of NPK ($N_0 P_0 K_0$, $N_{60} P_{30} K_{30}$, $N_{90} P_{45} K_{45}$, and $N_{120} P_{60} K_{60}$), one variety each of triticale (Delfin) and wheat ((HD-2204) and treated effluent. Growth parameters were studied at tillering, heading and milky grain stages and yield and grain quality, at harvest.

4.4.1 Growth parameters

All main plot, sub-plot and most of the interaction effect on all the growth parameters were significant. The data are presented in Table 71 to

Table 70. Effect of three levels of potassium and four levels of irrigation and of their interaction on lysine content (%) of triticale cv.Delfin cultivated with treated effluent.

Sub-plots (Irrigation levels)	Main plots K_0	K_{30}	K_{60}	Mean
I_0	3.38	3.35	3.30	3.34
I_1	3.48	3.43	3.38	3.43
I_2	3.58	3.52	3.53	3.54
I_3	3.63	3.61	3.60	3.61
Mean	3.51	3.47	3.45	

N.B. A uniform three irrigations were given during the expriment.

	C.D. at 5%
Main plot marginal means (M)	0.013
Sub-plot marginal means (S)	0.041
Main plot means at the same level of sub-plots (M x S)	N.S.
Sub-plot means at the same level of main plot (S x M)	0.062

N.S. - Non-significant

75 and are summarised below.

4.4.1.1 Shoot length per plant

It is evident from Table 71 that triticale was 3.68, 15.97 and 39.75% taller than wheat at the three growth stages. It may be noted that a gradual increase in shoot length from tillering to milky grain stage was recorded in both triticale and wheat but the increase was more pronounced in triticale than in wheat particularly at later stage.

Maximum shoot length was recorded with the treatment $N_{120}P_{60}K_{60}$ followed by N_{90} P_{45} K_{45} at all the three stages. The former showed an increase of 23.96, 31.76 and 19.89% over N_0 P_0 K_0 at the three successive stages.

Triticale interacted with all the sub-plot treatments to produced taller plants compared with wheat at all the three stages. It was also noted that triticale x N_{120} P_{60} K_{60} at all the three stages gave higher values that were critically different with wheat x N_{120} P_{60} K_{60}. The former showed an increase of 1.35, 21.06 and 42.58% over the latter at the three successive stages of growth.

N_{120} P_{60} K_{60} x triticale gave an increase of 20.49, 36.21 and 27.20% over N_0 P_0 K_0 x triticale while N_{120} P_{60} K_{60} x wheat recorded an increase of 27.70, 26.74 and 18.36% over the interaction N_0 P_0 K_0 x wheat at the three successive stages. A linear increase in shoot length was recorded in both triticale and wheat with the increase in fertiliser doses.

Table 71. Effect of four doses of fertiliser on shoot length (cm) of triticale and wheat cultivated with treated effluent at three stages of growth.

Sub-plots (Fertiliser doses)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
$N_0P_0K_0$	62.81	58.47	60.64	75.39	66.92	71.15	97.41	73.42	85.41
$N_{60}P_{30}K_{30}$	66.90	64.30	65.60	82.92	72.91	77.91	111.88	78.62	95.25
$N_{90}P_{45}K_{45}$	74.89	72.90	73.89	95.70	82.93	89.31	118.76	84.48	98.62
$N_{120}P_{60}K_{60}$	75.68	74.67	75.17	102.69	84.82	93.75	123.91	86.90	102.40
Mean	70.07	67.58		89.17	76.89		112.99	80.85	

N.B. A uniform three irrigations were given during the experiment.
V_1 - Delfin
V_2 - HD - 2204

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.347	1.130	0.878
Sub-plot marginal means (S)	0.493	0.236	0.416
Main plot means at the same level of sub- plot (MxS)	0.698	0.334	0.589
Sub- plot means at the same level of main plot(SxM)	0.677	1.139	0.961

4.4.1.2 Leaf number per plant

It may be noted from Table 72 that higher leaf number was recorded in triticale which was 45.17, 46.41 and 49.68% more than in wheat at the three successive stages.

Maximum leaf number was registered with N_{120} P_{60} K_{60}, followed by N_{90} P_{45} K_{45} while N_0 P_0 K_0 gave lowest the the value at all the three stages. An increase of 87.76, 98.0 and 143.4% over N_0 P_0 K_0 was recorded in N_{120} P_{60} K_{60} at the three stages.

Triticale showed more leaf number with all the sub-plot treatments compared to the respective values at all the three stages. It was further noted that both triticale and wheat showed best performance with N_{120} P_{60} K_{60} and the former showed an increase of 66.01, 69.59 and 70.01% over the latter at the three successive stages.

N_{120} P_{60} K_{60} x triticale gave an increase of 109.15, 118.24 and 174.06% over N_0 P_0 K_0 x triticale while N_{120} P_{30} K_{60} x wheat recorded an increase of 60.44, 71.16 and 104.62% over N_0 P_0 K_0 x wheat at the three successive stages. N_{120} P_{60} K_{60} interacted best with triticale and showed an increase of 109.15, 118.24, and 174.06% over N_0 P_0 K_0 while wheat with N_{120} P_{60} K_{60} showed an increase of 60.44, 71.16 and 104.62% N_0 P_0 K_0.

4.4.1.3 Tiller number per plant

It is evident from Table 73 that triticale significantly increase tiller

Table 72. Effect of four doses of fertiliser on leaf number of triticale and wheat cultivated with treated effluent at three stages of growth .

Sub-plots (Fertiliser doses)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
$N_0P_0K_0$	14.20	11.15	12.67	13.70	10.30	12.00	9.33	7.35	8.34
$N_{60}P_{30}K_{30}$	16.79	13.96	15.37	15.03	11.82	13.42	13.02	9.32	11.17
$N_{90}P_{45}K_{45}$	24.70	15.89	20.29	23.90	16.63	20.26	18.03	12.35	15.19
$N_{120}P_{60}K_{60}$	29.70	17.89	23.79	29.90	17.63	23.76	25.57	15.04	20.30
Mean	21.34	14.70		20.63	14.09		16.48	11.01	

N.B. A uniform three irrigations were given during the experiment.

V_1 - Delfin

V_2 - HD - 2204

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.254	0.627	0.473
Sub-plot marginal means (S)	0.488	0.523	0.691
Main plot means at the same level of sub- plot (MxS)	0.690	0.740	0.977
Sub- plot means at the same level of main plot(SxM)	0.638	0.853	0.943

Table 73. Effect of four doses of fertiliser on tiller number of triticale and wheat cultivated with treated effluent at three stages of growth.

Sub-plots (Fertiliser doses)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
$N_0P_0K_0$	3.13	2.34	2.73	3.13	2.07	2.60	3.24	2.02	2.63
$N_{60}P_{30}K_{30}$	4.61	3.26	3.93	4.62	3.05	3.83	4.81	3.05	3.93
$N_{90}P_{45}K_{45}$	6.26	5.28	5.77	6.28	4.92	5.60	6.28	5.27	5.77
$N_{120}P_{60}K_{60}$	7.92	5.81	6.86	7.94	5.43	6.68	8.24	5.29	6.76
Mean	5.48	4.17		5.49	3.86		5.64	3.90	

N.B. A uniform three irrigations were given during the experiment.
V_1 - Delfin
V_2 - HD - 2204

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.925	0.492	0.516
Sub-plot marginal means (S)	0.445	0.376	0.541
Main plot means at the same level of sub- plot (MxS)	0.629	0.532	0.765
Sub- plot means at the same level of main plot(SxM)	1.016	0.639	0.805

numbers by 31.41, 42.22 and 44.61% over wheat at the three stages. Tiller number was restricted in triticale from tillering stage to milky grain stage while there was a decrease in wheat as the crop matured.

Among the various fertiliser doses, $N_{120}\ P_{60}\ K_{60}$ *proved the best for tiller* production while $N_{90}\ P_{45}\ K_{45}$ was second best to it at all the three stages. $N_{120}\ P_{60}\ K_{60}$ showed an increase of 151.28, 156.92 and 157.03% over $N_0\ P_0\ K_0$ at the three stages.

Triticale produced more tillers compared to wheat at tillering, heading as well as milky grain stage. The former showed an increase of 36.31, 46.22 and 55.76% over wheat with $N_{120}\ P_{60}\ K_{60}$ and of 33.76, 51.20 and 60.39% with $N_0\ P_0\ K_0$.

Considering the S x M interactions, all values were critically different, except $N_0\ P_0\ K_0$ x wheat from $N_{60}\ P_{30}\ k_{30}$ x wheat and $N_{90}\ P_{45}\ K_{45}$ x wheat from $N_{120}\ P_{60}\ K_{60}$ x wheat at tillering and $N_{90}\ P_{45}\ K_{45}$ x wheat from $N_{120}\ P_{60}\ K_{60}$ x wheat at both heading and milky grain stages. $N_{120}\ P_{60}\ K_{60}$ x triticale gave an increase of 153.03, 153.67 and 154.32% over $N_0\ P_0\ K_0$ x triticale while $N_{90}\ P_{45}\ K_{45}$ x wheat gave an increase of 125.64, 137.68 and 169.89% over $N_0\ P_0\ K_0$ x wheat at the three stages. When the number of tillers was taken into account $N_{120}\ P_{60}\ K_{60}$ x triticale registered the maximum number followed by $N_{90}\ P_{45}\ K_{45}$ x triticale. $N_{120}\ P_{60}\ K_{60}$ x triticale showed an increase of 26.51, 26.43 and 31.21% over $N_{90}\ P_{45}\ K_{45}$ x triticale.

4.4.1.4 *Fresh weight per plant*

It is clear from Table 74 that fresh weight was more in triticale being 33.50 30.49 and 45.03% more than that of wheat at tillering, heading and milky grain stages respectively. A linear increase in fresh weight was observed from tillering to milky grain stage in triticale as well as in wheat.

It was noted that N_{120} P_{60} K_{60} recorded the maximum fresh weight, followed by N_{90} P_{45} K_{45} , N_{60} $P_{30}K_{30}$ and N_0 P_0 K_0 in that order at the the three successive stages studied. An increase of 51.34, 57.12 and 89.63% was recorded with N_{120} P_{60} K_{60} compared to N_0 P_0 K_0 at three stages.

It was found that triticale and wheat were comparatively closer in fresh weight when grown with no fertiliser while with N_{120} P_{60} K_{60} the difference was more pronounced. Triticale x N_{120} P_{60} K_{60} showed an increase of 44.98, 34.92 and 63.12% over wheat x N_{120} P_{60} K_{60} while triticale x N_0 P_0 K_0 showed an increase of 15.32, 29.74 and 35.52% over wheat x N_0 P_0 K_0 at the three stage respectively.

All the values for S x M interactions were critically different, except those for N_0 P_0 K_0 x wheat and N_{60} P_{30} K_{30} x wheat at the tillering stage which were at par. N_{120} P_{60} K_{60} x triticale gave an increase of 67.16, 59.78 and 104.31% over N_0 P_0 K_0 x triticale while N_{120} P_{60} K_{60} x wheat showed an increase of 32.97, 53.65 and 69.75% over N_0 P_0 K_0 x wheat at three stage. It is interesting to note that the increase in fresh weight was more conspicuous in triticale than in wheat.

Table 74. Effect of four doses of fertiliser on fresh weight (g) of triticale and wheat cultivated with treated effluent at three stages of growth.

Sub-plots (Fertiliser doses)	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
$N_0P_0K_0$	13.92	12.07	12.99	21.81	16.81	19.31	23.88	17.62	20.75
$N_{60}P_{30}K_{30}$	17.24	12.95	15.09	24.18	20.22	22.20	29.27	21.68	25.47
$N_{90}P_{45}K_{45}$	20.19	14.84	17.51	32.51	23.99	28.25	39.00	27.96	33.48
$N_{120}P_{60}K_{60}$	23.27	16.05	19.66	34.85	25.83	30.34	48.79	29.91	39.35
Mean	18.65	13.97		28.33	21.71		35.23	24.29	

N.B. A uniform three irrigations were given during the experiment.
V_1 - Delfin
V_2 - HD - 2204

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.165	1.263	0.257
Sub-plot marginal means (S)	0.800	0.926	0.568
Main plot means at the same level of sub- plot (MxS)	1.131	1.309	0.803
Sub- plot means at the same level of main plot(SxM)	0.990	1.608	0.731

4.4.1.5 Dry weight per plant

Table 75 indicates that dry weight of triticale differed critically with that of wheat at all the three stages and the difference was 24.04, 25.68 and 37.78% at tillering, heading and milky grain stages respectively.

On comparing the values for sub-plot means, it was found that all the treatments were critically different in their effect, except N_{90} P_{45} K_{45} and N_{120} P_{60} K_{60} at heading stage N_{120} P_{60} K_{60} gave the best performance, followed by N_{90} P_{45} K_{45} at all the three stages, while N_0 P_0 K_0 the control, accumulated the lowest dry weight, N_{120} P_{60} K_{60} showed an increase of 108.69, 114.32 and 119.33% over the control at the three samplings.

Triticale and wheat responded equally when grown with the lower dose (N_{60} P_{30} K_{30}) and the no fertiliser control (N_0 P_0 K_0) at tillering while with higher doses (N_{90} P_{45} K_{45} and N_{120} P_{60} K_{60}) both responded differently. At heading and milky grain stages, the effect was distinct, except that the two varieties recorded statistically equal dry weight under N_0 P_0 K_0 (control) at heading stage. It was also noted that both triticale and wheat showed the best performance with N_{120} P_{60} K_{60} at all three stages.

Sub-plot treatment gave critically different values with both main plot treatments at the three stages, except the higher doses (N_{90} P_{45} K_{45} and $N_{120}P_{60}K_{60}$) that gave statistically equal values at heading stage.

Table 75. Effect of four doses of fertiliser on dry weight (g) of triticale and wheat cultivated with treated effluent at three stages of growth.

Sub-plots (Fertiliser doses)	Stages of sampling								
	Tillering (T)			Heading (H)			Milky grain (M)		
	Main plots								
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
$N_0P_0K_0$	2.50	2.56	2.53	3.77	3.64	3.70	8.06	6.94	7.50
$N_{60}P_{30}K_{30}$	3.58	2.97	3.27	5.83	4.48	5.15	10.23	8.35	9.29
$N_{90}P_{45}K_{45}$	4.85	3.59	4.22	9.00	6.63	7.81	16.11	10.83	13.47
$N_{120}P_{60}K_{60}$	6.02	4.55	5.28	8.80	7.06	7.93	19.73	13.17	16.45
Mean	4.23	3.41		6.85	5.45		13.53	9.82	

N.B. A uniform three irrigations were given during the experiment.
V_1 - Delfin
V_2 - HD - 2204

	C.D. at 5%		
	T	H	M
Main plot marginal means (M)	0.567	0.684	1.482
Sub-plot marginal means (S)	0.468	0.559	0.708
Main plot means at the same level of sub- plot (MxS)	0.661	0.791	1.001
Sub- plot means at the same level of main plot(SxM)	0.766	0.920	1.625

4.4.2 Yield parameters

The various yield characteristics were found to be affected significantly by the NPK doses both in the case of triticale and wheat.

4.4.2.1 Ear number per plant

It is evident from Table 76 that triticale showed critically different value for ear production compared to wheat and recorded an increase of 60.84% over wheat.

All the sub-plot treatments were critically different in their effect with one another. N_{120} P_{60} K_{60} showed the best performance, followd by N_{90} P_{45} K_{45} and the former recorded an increase of 177.08% over N_0 P_0 K_0 .

Triticale showed critically different values as compared to wheat with each sub-plot treatment. It was also noted that both varieties gave best performance with N_{120} P_{60} K_{60}, with triticale recording an increase of 52.85% over wheat. Maximum number of ear was noted in triticale x N_{120} P_{60} K_{60} and lowest in wheat x N_0 P_0 K_0.

Triticale showed a linear increase in ear production from control to N_{120} P_{60} K_{60}. On the other hand wheat responded differently, giving statistically equal values for N_0 P_0 K_0 and N_{60} P_{30} K_{30} and for N_{90} P_{45} K_{45} and N_{120} P_{60} K_{60}. N_{120} P_{60} K_{60} x triticale recorded an increase of 176.28 and 28.02% over N_0 P_0 K_0 x triticale and N_{90} P_{45} K_{45} x triticale respectively. N_{90} P_{45} K_{45} x wheat showed an increase of 118.42% over N_0 P_0 K_0 x wheat.

Table 76 Effect of four doses of fertiliser on ear number of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	2.91	1.9	2.40
$N_{60}P_{30}K_{30}$	4.15	2.0	3.07
$N_{90}P_{45}K_{45}$	6.28	4.15	5.21
$N_{120}P_{60}K_{60}$	8.04	5.26	6.65
Mean	5.34	3.32	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	1.082
Sub-plot marginal means (S)	0.441
Main plot means at the same level of sub-plots (M x S)	0.624
Sub-plot means at the same level of main plot (S x M)	1.150

4.4.2.2 Length per ear

Longer ears were produced by triticale which recorded an increase of 53.81% in ear length over wheat (Table 77).

All the values for sub-plot means were critically different from one another, N_{120} P_{60} K_{60} being the best and recording 53.66% increase over $N_0P_0K_0$.

Triticale showed much higher value than wheat with each sub-plot treatment. Triticale x N_{120} P_{60} K_{60} recorded an increase of 67.11% over wheat x N_{120} P_{60} K_{60}

All the sub-plot treatments showed critically different values with both triticale and wheat, except N_0 P_0 K_0 x wheat and N_{60} P_{30} K_{30} x wheat which were at par. N_{120} P_{60} K_{60} x triticale proved best for length per ear, followed by N_{90} P_{45} K_{45} x triticale. N_{120} P_{60} K_{60} x wheat registered an increase of 32.91 and 9.39% over N_0 P_0 K_0 x wheat and N_{90} P_{45} K_{45} x wheat respectively. On the other hand N_{120} P_{60} K_{60} x triticale recorded an increase of 69.38 and 13.75% over N_0 P_0 K_0 x triticale and N_{90} P_{45} K_{45} x triticale respectively.

4.4.2.3 Ear weight per plant

It is evident the Table 78 that, like other yield parameters, triticale produced heavier ears than wheat and showed an increase of 126.06% over the later.

Table 77. Effect of four doses of fertiliser on length per ear (cm) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots Delfin	HD-2204	Mean
$N_0P_0K_0$	14.70	11.21	12.95
$N_{60}P_{30}K_{30}$	17.64	11.74	14.69
$N_{90}P_{45}K_{45}$	21.89	13.62	17.75
$N_{120}P_{60}K_{60}$	24.90	14.90	19.90
Mean	19.78	12.86	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	1.149
Sub-plot marginal means (S)	0.330
Main plot means at the same level of sub-plots (M x S)	0.467
Sub-plot means at the same level of main plot (S x M)	1.174

Table 78 . Effect of four doses of fertiliser on ear weight (g) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots: Delfin	HD-2204	Mean
$N_0P_0K_0$	5.77	2.37	4.07
$N_{60}P_{30}K_{30}$	7.20	3.60	5.40
$N_{90}P_{45}K_{45}$	10.69	4.81	7.75
$N_{120}P_{60}K_{60}$	12.45	5.19	8.82
Mean	9.02	3.99	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.349
Sub-plot marginal means (S)	0.349
Main plot means at the same level of sub-plots (M x S)	0.494
Sub-plot means at the same level of main plot (S x M)	0.529

Treatment $N_{120} P_{60} K_{60}$ proved the best and registered an increase of 116.70% over $N_0 P_0 K_0$ and of 13.8% over $N_{90} P_{45} K_{45}$.

It was noted that triticale x $N_{120} P_{60} K_{60}$ and wheat x $N_{120} P_{60} K_{60}$ were the best for ear weight while $N_0 P_0 K_0$ with both triticale and wheat were the poorest among all the interactions when the values of main plot means at the same level of sub-plot were compared.

All the interaction values for S x M were critically different, except $N_{90} P_{45} K_{45}$ x wheat and $N_{120} P_{60} K_{60}$ x wheat. $N_{120} P_{60} K_{60}$ x triticale recorded an increase of 115.77 and 16.46% over $N_0 P_0 K_0$ and $N_{90} P_{45} K_{45}$ x triticale respectively, whereas, $N_{90} P_{45} K_{45}$ x wheat showed an increase of 102.95% over $N_0 P_0 K_0$ x wheat.

4.4.2.4 Spikelet number per ear

Triticale proved better than wheat and recorded 98.04% more spikelets (Table 79).

Among the sub plot treatments, $N_{120} P_{60} K_{60}$ recorded the highest spikelet number followed by $N_{90} P_{45} K_{45}$, $N_{60} P_{30} K_{30}$ and $N_0 P_0 K_0$ in that order. $N_{120} P_{60} K_{60}$ produced 6.28 and 41.69% more spikelets than $N_{90} P_{45} K_{45}$ and $N_0 P_0 K_0$.

Spikelet number was more in each triticale x fertiliser interaction compard to the respective wheat x fertiliser combination. $N_{120} P_{60} K_{60}$ proved best, followed by N_{90}, $P_{45} K_{45}$ with both triticale and wheat and the triticale

Table 79 . Effect of four doses of fertiliser on spikelet number of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	23.70	12.33	18.01
$N_{60}P_{30}K_{30}$	28.58	13.37	20.97
$N_{90}P_{45}K_{45}$	31.66	16.36	24.01
$N_{120}P_{60}K_{60}$	33.70	17.34	25.52
Mean	29.41	14.85	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	3.021
Sub-plot marginal means (S)	0.514
Main plot means at the same level of sub-plots (M x S)	0.727
Sub-plot means at the same level of main plot (S x M)	3.034

recorded an increase of 94.34, 93.52 and 92.21% over wheat when grown with N_{120} P_{60} K_{60}, N_{90} P_{45} K_{45} and N_0 P_0 K_0 respectively.

N_{60} P_{30} K_{30} was different from N_0 P_0 K_0 as well as N_{90} P_{45} K_{45} and N_{120} P_{60} K_{60} in its effect on triticale, while the two higher doses had equal effect on this main plot. On the other hand in the case of wheat each lower dose was equal in its effect to the immediately higher dose.

4.4.2.5 Grain number per ear

Table 80 indicates that triticale proved superior to wheat and recorded 10.01% more grain number per ear.

The highest dose (N_{120} P_{60} K_{60}) proved best and recorded an increase of 64.03% over N_0 P_0 K_0 and 6.87% over N_{90} P_{45} K_{45}.

Triticale intereacted with each sub-plot treatment to record higher grain number than wheat. Triticale x N_{120} P_{60} K_{60} and triticale x N_0 P_0 K_0 were superior than wheat x N_{120} P_{60} K_{60} and wheat x N_0 P_0 K_0 among all the interactions.

N_{120} P_{60} K_{60} interacting with triticale recorded an increase of 7.99 and 67.63% over N_{90} P_{45} K_{45} x triticale and N_0 P_0 K_0 x triticale respectively while N_{120} P_{60} K_{60} x wheat showed an increase of 5.61 and 60.11% over in N_{90} P_{45} K_{45} x wheat and N_0 P_0 K_0 x wheat respectively.

Table 80. Effect of four doses of fertiliser on grain number of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots: Delfin	Main plots: HD-2204	Mean
$N_0P_0K_0$	32.23	29.96	31.09
$N_{60}P_{30}K_{30}$	39.05	36.03	37.54
$N_{90}P_{45}K_{45}$	50.03	45.42	47.72
$N_{120}P_{60}K_{60}$	54.03	47.97	51.00
Mean	43.83	39.84	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	1.453
Sub-plot marginal means (S)	1.110
Main plot means at the same level of sub-plots (M x S)	1.570
Sub-plot means at the same level of main plot (S x M)	1.888

4.4.2.6 1,000 grain weight

Table 81 indicates that unlike the other yield attributed 1,000 grain weight in wheat was 5.12% more than that of triticale.

All the fertiliser treatments were critically different in their effect and $N_{120} P_{60} K_{60}$ produced heaviest seeds, followed by $N_{90} P_{45} K_{45}$. The former showed an increase an 15.5 and 5.76% over $N_0 P_0 K_0$ and $N_{90} P_{45} K_{45}$ respectively.

Compared to triticale wheat produced heavier grains with each of the fertiliser dose. Wheat x $N_{120} P_{60} K_{60}$ and wheat x $N_0 P_0 K_0$ gave an increase of 12.05 and 4.91% over triticale x $N_{120} P_{60} K_{60}$ and triticale x $N_0 P_0 K_0$ respectively.

$N_{60} P_{30} K_{30}$ x triticale and $N_0 P_0 K_0$ x triticale produced grains that were at par in 1,000 grain weight with those produced by $N_{60} P_{30} K_{30}$ x wheat and $N_0 P_0 K_0$ x wheat respectively while with higher doses $N_{90} P_{45} K_{45}$ and $N_{120} P_{60} K_{60}$ both varieties responded differently. Triticale again gave values at par with higher doses ($N_{90} P_{45} K_{45}$ and $N_{120} P_{60} K_{60}$. $N_{90} P_{45} K_{45}$ x triticale recorded an increase of 11.62% over $N_0 P_0 K_0$ x triticale while $N_{120} P_{60} K_{60}$ x wheat registered an increase of 19.21% over $N_0 P_0 K_0$ x wheat.

4.4.2.7 Grain yield

It is evident from Table 82 that triticale recorded 6.60% more grain yield than wheat.

Table 81. Effect of four doses of fertiliser on 1,000 grain weight (g) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	35.37	37.11	36.24
$N_{60}P_{30}K_{30}$	36.02	38.65	37.33
$N_{90}P_{45}K_{45}$	38.22	40.94	39.58
$N_{120}P_{60}K_{60}$	39.48	44.24	41.86
Mean	38.27	40.23	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	1.437
Sub-plot marginal means (S)	0.875
Main plot means at the same level of sub-plots (M x S)	1.238
Sub-plot means at the same level of main plot (S x M)	1.694

Table 82 . Effect of four doses of fertiliser on grain yield (q/ha) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots: Delfin	HD-2204	Mean
$N_0P_0K_0$	31.15	29.85	30.50
$N_{60}P_{30}K_{30}$	37.95	35.24	36.59
$N_{90}P_{45}K_{45}$	50.41	46.99	48.70
$N_{120}P_{60}K_{60}$	52.81	49.58	51.19
Mean	43.08	40.41	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.110
Sub-plot marginal means (S)	0.918
Main plot means at the same level of sub-plots (M x S)	1.299
Sub-plot means at the same level of main plot (S x M)	1.129

Among the sub-plot treatments, $N_{120} P_{60} K_{60}$ proved best, followed by $N_{90} P_{45} K_{45}$ and recorded an increase of 67.83% over $N_0 P_0 K_0$ and 5.11% over $N_{90} P_{45} K_{45}$.

Triticale gave higher grain yield with all fertiliser doses compared with respective wheat x fertiliser combinations. Both triticale and wheat responded best with $N_{120} P_{60} K_{60}$ followed by $N_{90} P_{45} K_{45}$. Triticale recorded an increase of 6.51 and 4.35% over wheat when grown with and $N_0 P_0 K_0$ respectively.

When grown under $N_{120} P_{60} K_{60}$ fertiliser treatment both varities gave the best performance. $N_{120} P_{60} K_{60}$ x triticale recorded an increase of 69.53% over $N_0 P_0 K_0$ x triticale. Similarly $N_{120} P_{60} K_{60}$ x wheat registered an increase of 66.09% over $N_0 P_0 K_0$ x wheat it may be pointed out that $N_{120} P_{60} K_{60}$ x triticale recorded 52.81 q/ha. grain yield which was the highest among all the interaction combinations of triticale as well as wheat.

4.4.2.8 Straw yield

It is evident from Table 83 that triticale proved better than wheat for straw production.

$N_{120} P_{60} K_{60}$ proved best, followed by $N_{90} P_{45} K_{45}$, $N_{60} P_{30} K_{30}$ and $N_0 P_0 K_0$ in that order. $N_{120} P_{60} K_{60}$ recorded an increase of 58.49% over $N_0 P_0 K_0$ and of 9.08% over $N_{90} P_{45} K_{45}$.

Triticale, together with all sub-plot treatment combinations, gave higher straw yield compared to respective combinations of wheat with

Table 83. Effect of four doses of fertiliser on straw yield (q/ha) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots: Delfin	Main plots: HD-2204	Mean
$N_0P_0K_0$	82.78	77.51	80.14
$N_{60}P_{30}K_{30}$	93.94	88.13	91.03
$N_{90}P_{45}K_{45}$	120.10	112.78	116.44
$N_{120}P_{60}K_{60}$	129.49	124.56	127.02
Mean	106.57	100.74	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.918
Sub-plot marginal means (S)	1.048
Main plot means at the same level of sub-plots (M x S)	1.481
Sub-plot means at the same level of main plot (S x M)	1.519

fertiliser doses. Like most of the parameters mentioned so far, both triticale and wheat perfrormed best when interacting with N_{120} P_{60} K_{60} followed by N_{90} P_{45} K_{45}. Triticale recorded an increase of 3.95, 6.49 and 6.79% over wheat N_{120} P_{60} K_{60}, N_{90} P_{45} K_{45} and N_0 P_0 K_0 respectively.

It was noted that all sub-plot treatments interacting with both triticale and wheat gave critically different values. N_{120} P_{60} K_{60} gave the best performance, followed by N_{90} P_{45} K_{45}, while interacting with both varieties. N_{120} P_{60} K_{60} x triticale recorded an increase of 7.81 and 56.42% over N_{90} P_{45} K_{45} x triticale and N_0 P_0 K_0 x triticale respectively. While N_{120} P_{60} K_{60} x wheat registered an increase of 10.44 and 60.70% over N_{90} P_{45} K_{45} x wheat and N_0 P_0 K_0 x wheat respectively.

4.4.3 Grain quality

Main plot, sub-plot and interaction effects on grain quality were significant. The data are presented in Table 84-88 and are summarised below.

4.4.3.1 Protein content

It is evident from Table 84 that triticale contained 22.78% more protein compared to wheat.

It was noted that N_{120} P_{60} K_{60} closely followed by N_{90} P_{45} K_{45} proved the best fertiliser dose while lowest protein content was obtained with N_0 P_0 K_0.

Triticale possessed higher protein content when interacting with the re-

Table 84. Effect of four doses of fertiliser on grain protein content (%) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	12.34	9.59	10.96
$N_{60}P_{30}K_{30}$	13.68	11.72	12.70
$N_{90}P_{45}K_{45}$	14.81	11.98	13.39
$N_{120}P_{60}K_{60}$	15.22	12.36	13.79
Mean	14.01	11.41	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.189
Sub-plot marginal means (S)	0.170
Main plot means at the same level of sub-plots (M x S)	0.240
Sub-plot means at the same level of main plot (S x M)	0.268

spective sub plot treatments compared to wheat. It was noted that triticale x $N_{120} P_{60} K_{60}$ gave maximum value which was 23.13% higher than that for wheat x $N_{120} P_{60} K_{60}$ while triticale x $N_0 P_0 K_0$ showed an increase of 28.67% over wheat x $N_0 P_0 K_0$

$N_{120} P_{60} K_{60}$ x triticale gave 15.22% protein which was the maximum in all the combinations of triticale and wheat. On the other hand, $N_{120} P_{60} K_{60}$ x wheat recorded 12.36% protein content. $N_{120} P_{60} K_{60}$ x triticale showed an increase of 23.33% over $N_0 P_0 K_0$ x triticale while $N_{120} P_{60} K_{60}$ x wheat recorded an increase of 28.88% over $N_0 P_0 K_0$ x wheat.

4.4.3.2 Carbohydrate content

Like protein content, triticale gave 3.52% higher carbohydrate content than wheat (Table 85).

The carbohydrate content with higher doses of fertiliser ($N_{90} P_{45} K_{45}$ and $N_{120} P_{60} K_{60}$) were at par and $N_{90} P_{45} K_{45}$ gave an increase of 6.03% over $N_0 P_0 K_0$.

Triticale together with all sub-plot treatments showed critically different values compared to wheat. Triticale with $N_0 P_0 K_0$ and $N_{120} P_{60} K_{60}$ gave an increase of 4.56 and 3.86% over wheat with the respective doses.

Considering the sub-plots, both triticale and wheat responded to each dose more or less similarly. Application of fertiliser was responsible for a significant increase. In wheat also the trend was more or less similar where

Table 85. Effect of four doses of fertiliser on grain carbohydrate content (%) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	75.56	72.26	73.91
$N_{60}P_{30}K_{30}$	78.06	76.73	77.39
$N_{90}P_{45}K_{45}$	79.90	76.84	78.37
$N_{120}P_{60}K_{60}$	80.13	77.15	78.64
Mean	78.41	75.74	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.411
Sub-plot marginal means (S)	0.516
Main plot means at the same level of sub-plots (M x S)	0.729
Sub-plot means at the same level of main plot (S x M)	0.728

N_{60} P_{30} K_{30}, N_{90} P_{45} K_{45} and N_{120} P_{60} K_{60} at par. However, it differed with N_{60} P_{30} K_{30} and N_0 P_0 K_0 N_{90} P_{45} K_{45} x triticale recorded an increase of 5.74% over N_0 P_0 K_0 x triticale. On the other hand N_{60} P_{30} K_{30} x wheat recorded an increase of 6.18% over N_0 P_0 K_0 x wheat.

4.4.3.3 Lysine content

Like carbohydrate and protein content, triticale gave higher lysine content as compared to wheat (Table 86). Triticale showed an increase of 63.84% over wheat.

Contrary to the earlier considered quality parameters, N_0 P_0 K_0 proved best for lysine content and there was gradual decrease with increase of fertiliser dose. N_0 P_0 K_0 gave an increase of 10.48% over N_{120} P_{60} K_{60}, while N_{60} P_{30} K_{30} and N_{90} P_{45} K_{45} gave at par values.

Triticale interacting with all sub-plot treatments, gave critically different values from comparable wheat combinations. Lysine content was highest in both triticale and wheat with N_0 P_0 K_0 triticle x N_0 P_0 K_0 gave an increase of 65.02% over wheat x N_0 P_0 K_0. On the other hand, triticale x N_{120} P_{60} K_{60} gave an increase of 63.54% over wheat x N_{120} P_{60} K_{60}.

Triticale showed decrease in lysine content with increase in fertiliser levels while wheat wheat gave values at par in all fertiliser doses in other words there was no effect of fertilisers on wheat when lysine content was considered.

Table 86. Effect of four doses of fertiliser on grain lysine content (%) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	3.68	2.23	2.95
$N_{60}P_{30}K_{30}$	3.51	2.16	2.83
$N_{90}P_{45}K_{45}$	3.45	2.11	2.78
$N_{120}P_{60}K_{60}$	3.32	2.03	2.67
Mean	3.49	2.13	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.080
Sub-plot marginal means (S)	0.057
Main plot means at the same level of sub-plots (M x S)	0.081
Sub-plot means at the same level of main plot (S x M)	0.101

4.4.3.4 Protein yield

Triticale yielded more protein as compared to wheat (Table 87).

It was noted that N_{120} P_{60} K_{60} proved the best fertiliser dose to protein yield, followed by N_{90} P_{45} K_{45}, N_{60} P_{30} K_{30} and N_0 P_0 K_0 in that order.

Triticale x N_{120} P_{60} K_{60} gave an increase of 31.20% over wheat x N_{120} P_{60} K_{60} while triticale x N_0 P_0 K_0 showed an increase of 33.33% over wheat x N_0 P_0 K_0.

There was linear increase in protein yield with increase in fertiliser doses as a result of interaction with each variety. N_{120} P_{60} K_{60} x triticale yielded maximum protein than any other combination and recorded an increase of 109.11% over N_0 P_0 K_0 x triticale. On the other hand N_{120} P_{60} K_{60} x wheat registered an increase of 112.5% over N_0 P_0 K_0 x wheat.

4.4.3.5 Carbohydrate yield

Triticale showed an increase of 10.19% in carbohydrate yield over wheat (Table 88).

A linear increase in carbohydrate yield was obtained with increase in fertiliser doses. Thus, the treatment N_{120} P_{60} K_{60} proved best and recorded an increase of 77.71% over N_0 P_0 K_0.

Triticale interacted with each sub-plot treatment to give statistically different value than that given by the comparable wheat combination.

Table 87. Effect of four doses of fertiliser on protein yield (q/ha) of triticale and wheat cultivated with treated effluent.

Sub-plots (Fertiliser doses)	Main plots: Delfin	HD-2204	Mean
$N_0P_0K_0$	3.84	2.88	3.36
$N_{60}P_{30}K_{30}$	5.18	4.13	4.65
$N_{90}P_{45}K_{45}$	7.46	5.63	6.54
$N_{120}P_{60}K_{60}$	8.03	6.12	7.07
Mean	6.12	4.69	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.078
Sub-plot marginal means (S)	0.120
Main plot means at the same level of sub-plots (M x S)	0.169
Sub-plot means at the same level of main plot (S x M)	0.162

Table 88. **Effect of four doses of fertiliser on carbohydrate yield (q/ha) of triticale and wheat cultivated with treated ef fluent.**

Sub-plots (Fertiliser doses)	Main plots		Mean
	Delfin	HD-2204	
$N_0P_0K_0$	23.53	21.79	22.66
$N_{60}P_{30}K_{30}$	29.62	27.03	28.32
$N_{90}P_{45}K_{45}$	40.27	36.10	38.18
$N_{120}P_{60}K_{60}$	42.31	38.24	40.27
Mean	33.93	30.79	

N.B. Uniform three irrigations were given during the experiment

	C.D. at 5%
Main plot marginal means (M)	0.368
Sub-plot marginal means (S)	0.734
Main plot means at the same level of sub-plots (M x S)	1.038
Sub-plot means at the same level of main plot (S x M)	0.955

Triticale x N_{120} P_{60} K_{60} gave the maximum carbohydrate yield which was 10.64% higher than that for wheat x N_{120} P_{60} K_{60}. On the other hand, Triticale x N_0 P_0 K_0 gave an increase of 7.98% over wheat x N_0 P_0 K_0.

When the S x M interactions were considered, it was found that all the sub-plot treatments showed critically different in values when interacting with both the varieties. Maximum carbohydrate yield was obtained in N_{120} P_{60} K_{60} x triticale. which showed an increase of 79.81% over N_0 P_0 K_0 x triticale. N_{120} P_{60} K_{60} x wheat gave an increase of 75.49% over N_0 P_0 K_0 x wheat.

CHPATER 5

DISCUSSION

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CHAPTER 5

DISCUSSION

Apart from its genetic constitution, the growth, yield and quality of a plant is greatly influenced by environmental factors, including available nutrients, soil and water. Quality of water is considered to be of paramount importance to ensure successful agriculture. Directly or indirectly, it affects mineral uptake and almost every morpho-physiological process in the plant and thus has profound influence on growth, development, yield and quality.

5.1 Germination

The major events occuring during seed germination are imbibition of water, enzyme activation, initiation of embryo growth, rupture of seed coat, emergence of seedling and, finally, establishment .of the young plant (Copeland, 1976). All these processes require a particular combination of light, temperature, water and nutrients for proceeding at optimum rate (Varner, 1965).

In Experiment 1, no difference was noted in the percentage of seed germination under treated effluent and ground water irrigation (Table 13). This established the suitability of the former for the purpose of irrigation.

Among the four cultivars tested in Experiment 1, wheat exhibited maximum seed germination, followed by Delfin, Driera and TL-419, in that order (Table 13). The most likely reasons for the poor germinability of triticale may be: *(i)* being the outcome of intergeneric cross, it shows poor germination, (ii) frequent initiation of germination of grain during maturation, (iii) sub-normal development of embryo and endosperm which fails to sustain healthy germination (Zillinsky and Borlaug, 1971). Moreover, the observed difference in germinability of various triticale strains could possibly be attributed to the variability in the genetic make up of the cultivars tested (Abdalla et al., 1986; Inam et al., 1982 a). The most noteworthy observation, however, was that Delfin exhibited almost the same percentage of seed germination as the local wheat check (HD-2204) and interacted highly satisfactorily with treated effluent (Table 13).

5.2. Growth parameters

In both Experiment 1 and 2, treatd effluent proved superior to ground water for the growth of the both triticale and wheat showing greater height, leaf number, tiller number, fresh weight and dry matter production. This may be because it contained additional nutrients, like sulphate, calcium, potassium, sodium and phosphate, that reached the plants via the soil (Table 6) and, therefore, could possibily result in increased growth. Ajmal and Khan (1985) and Singh and Mishra (1987) noted that the concentration of water-soluble salts was lower in pot soil supporting the experimental plants compared to the pot soil without plants on irrigation with effluent, indicating the uptake of nutrients by the crop plant from the effluent through the soil.

Similar results were also obtained by other researchers where crops irrigated with diluted effluent obtained from sources other than oil refinery exhibited increased growth parameters (Rajannan and Oblisami, 1979; Singh *et al.* 1985; Srivastava and Sahai, 1987; Veer and Lata, 1987; Neelam and Sahai, 1988).

Among the cultivars (Experiment 1), Delfin performed best followed by Driera, wheat and TL-419. The superiority of Delfin manifested itself early at the tillering stage and was maintained throughout the growth, period, resulting in higher fresh and dry weight. In this connection, special attention may also be drawn to higher tiller production (Table 16) and higher net assimilation rate (Table 19) of Delfin over the other triticales as well as wheat. These differences can be attributed to genetic variations and may presumably be responsible for the differences in efficiency of absorption and subsequent utilisation of essential nutrients from the soil. In fact, sufficient information is available where genotypes have been found to differe considerably in their response to the surroundings and in their ability not only in absorption but also in translocation and accumulation of nutrients. Such varietal differences are well known in cereals, including triticale, (Millikan, 1961; Vose, 1963; Langer, 1966; Inam, 1978; Ashfaq, 1986; Moinuddin, 1987).

The quantity of irrigant has profound effect on the growth of crops. In Experiment 2, various levels of irrigation (I_0 to I_4) had significant differential effect on the growth parameters. Supply of water to growing points is the most important factor affecting growth in cereals. The better performance of the crop (Delfin) with increase in irrigation levels is in agreement with other published data (Singh *et al.*, 1978; Aggarwal and Sinha, 1987) as increasing the frequency of irrigation increases the consumptive use of water (Rathore and Singh, 1973; 1978; Patil and Bathkal, 1975). on the other hand, no irrigation (water stress) was responsible for the poor performance of the crop. It may be pointed out that water deficit may be related directly to turgor pressure. Even small reduction in the latter could thus decreasing the rate of absorption of carbon dioxide, bring about closure of stomata which would reduced photosynthetic rates, low turgor pressure also results in decreased leaf area and hence the extent of effective photosynthetic surface as it reduces cell size. In addition, water deficit adversely affects stem elongation (Jain and Misra, 1972) and is responsible for reduced nutrient uptake (Tanguilig *et al.* 1987) in crops due to decreased transpiration and impaired active nutrient absorption. Erlandsson (1975) also opined that any change in the water potential of plants caused by water stress has an effect on the active ion uptake mechanism. Evidence of decreased ion absorption due to reduced root absorption power as affected by water stress has been provided by Dunham and Nye (1976). The cumulative effect of these adversely affected processes reflected clearly in Experiment 2 in the highly reduced dry matter production in the control given no irrigation (Table 37) at all the three growth stages.

It is interesting to note that I_3 and I_4 were at par in their effect at the milky grain stage, particularly under treated effluent irrigation, proving the sufficiency of only three irrigations for proper growth of triticale.

In Experiment 3, the application of 30 as well as 60 kg potassium per hectare together with each level of irrigation with treated effluent proved much better for growth parameters than the respective controls without potassium (Tables 53-59). Since potassium has been reported to augment cell division and cell expansion (Mengel, 1978), the increase in shoot length is plausible. As a result, there is increase in leaf number which resulted in enhanced production of photosynthates and their subsequent accumulation in the form of dry matter (Mengel, 1983). The beneficial effect of potassium is of particular importance, since potassium reduces water loss by reducing transpiration (Brag, 1972; Saxena, 1985). Thus, to potassium application compensated for the ill effects of water stress. Beringer and Trolldenier (1978) reported that plants fertilised with potassium remain turgid and green for a longer period.

Under effluent irrigation (Experiment 4), triticale cultivar Delfin performed better than the wheat check and exhibited better plant height, tiller number, leaf number, fresh weight and dry weight (Tables 71-75).

The addition of fertiliser to treated effluent had a further beneficial effect on all the vegetative growth characteristics, sub-plot treatment N_{120} P_{60} K_{60} proving best. The growth of plant organs results from orderly cell division, expansion, and differentiation. These processes are dependent on proper supply of nutrients (Moorby and Besford, 1983) that influences plant growth both directly by providing vital macromolecules and indirectly, via their effects on the supply of assimilates and growth substances. The present findings also indicated that, during the vegetative phase, requirement for fertilisers increased with age which is well known for plants in general. The beneficial effect of fertiliser application revealed in the present study is in conformity with the results of a large number of workers in India and abroad. Mention may be made of the work of Acosta (1973), Kiss (1973) Afridi *et al.* (1977), Agarwal (1977), Inam (1978), Tahir (1978), Kalra and Dhiman (1979), Cherginets *et al.* (1980), Ponce *et al.* (1981) and Ashfaq *et al.* (1983, b), among the workers on triticale.

5.3 Proline content

In Experiment 2 more proline accumulation was noted in plants cultivated under treated effluent irrigation as compared to ground water. This increase in proline might be due to more salts in effluent compared to the groundwater.

Furthermore, in Experiments 2 and 3, there was a linear decrease in the proline content with increase in irrigation levels from I_0 at all the three stages. It has been established that proline accumulates in plant when they face adverse conditions. Durig the period of water stress a range of amino acids accumulates in the plant but the most frequent and extensive response is an increase in the the concentration of proline (Singh *et al.*, 1973 a,b; Mukherji, 1974; Pleg and Aspinall, 1981; Mengel and Kirkby, 1982; Sairam and Dube, 1984; Jorge *et al.*, 1988 ;Veeranjaneyulu and Kumari, 1989; Khan, 1991; Umar *et al.*, 1991). Its accumulation is supposed to decrease the osmotic potential of the cell so as to maintain a postive gradient for water uptake and to reduce water loss from the cell during stress conditions (Mengel and Kirkby, 1982).

In Experiment 3, increase in potassium levels from K_0 to K_{60} was associated with an increase in the proline content at all the stages of growth. Krishnasastry (1985) reported that potassium increases proline in finger millet and groundnut as a result of promotion in proline biosynthesis via potassium mediated arginase activity. Similar results have also been reported by Mukherji (1974), Udaykumar *et al.*, (1976), Marcano (1981), Khan (1991) and Umar *et al.* (1991). The role of potassium in maintaining osmotic potential of the plant under water stress condition was complimental by the accumulation of proline and the two together ensured plant survival better under stress condition.

5.4 Relative water content (RWC)

The productivity of a crop is determined by its environment of which water deficit has long been recognised as the chief limiting factor. Lower values of RWC were obtained due to water stress.

In Experiments 2 and 3 a decrease in relative water content due to water stress was evident (Table 39,58) at all the three stages of growth. Rajagopal *et al.* (1977) and Singh and Gupta (1983) also reported a similar decrease in relative water content under water stress condition. It is interesting to note that, under the same level of irrigation, treated effluent gave higher values for RWC as noted earlier.

In Experiment 3 an increase in RWC with the increase in potassium level under the same water regime was noted (Table 58). Water stress decreased RWC significantly which was alleviated due to potassium through better water retention by plants. The increase in RWC may be due to increase in proline, organic acids, sugars and organometallo complexes (Dwivedi et al. 1986 a, b). These molecules might raise leaf water content and make it available for succeeding steps in plant metabolism. Rajagopal (1985) and Umar *et al.* (1991) have also attributed a noteworthy role of potassium in achieving water economy among plants.

5.5 Yield parameters

Yield is the final manifestation of morphological, physiological and biochemical traits of a crop. These traits are, in turn, dependent upon various environmental factors, including water and essential nutrients.

In Experiment 1 and 2 it was noted that, compared to ground water, all the cultivars gave more yield under treated effluent irrigation. It may be recalled that treated effluent also proved superior in its effect on growth parameters in these experiments as discussed in p. It is reasonable to presume that the better effect on these characteristics manifested itself in improving such yield parameters as ear number, ear weight, 1,000 grain weight and grain number which cumulatively accounted for higher grain yield (Tables 20-26; 40-46). From the same logic, the higher straw yield under treated effluent could be expected on the basis of the better effect on vegetative growth. These findings are in agreeement with earlier reports of Day *et al.* (1975), Day and Tucker (1977), Veer and Lata (1987).

Delfin performed best among three cultivars of triticale and even surpassed the local wheat check in Experiment 1 with regard to final yield (Table 26) inspite of its slightly lower percentage germination than wheat (Table 13). This superiority of Delfin was due to its better yield-attributing parameters, including ear number, ear length, ear weight, and grain number compared to the other cultivars (Tables 20-24). The superior yielding ability of Delfin has also been noted earlier at Aligarh by Moinuddin *et al.* (1990 a, b). It is note worthy that among the yield parameters wheat could surpass Driera and TL-419 only in 1,000 grain weight (Table 25) which highlights its superiority in the production and translocation of photosynthates to the grains. Not only the higher 1,000 grain weight but also its much better germination percentage (Table 13) which resulted in a thicker stand (higher plant density) enabled wheat to surpass Driera and TL-419 triticales in grain as well as straw yield.

The crucial role of water to ensure a good yield is well known. It can be seen from the Table 46 (Experiment 2) that yield was lowest in I_0 (water stress condition). On the other hand, an upward trend was noted in all yield attributing parameters (ear number, ear length, ear weight, spikelet number, grain number 1,000 grain weight as well as grain yield itself with the increase in number of irrigations. Proper frequency of irrigation is known to increase the consumptive use of water and results in enhanced yield attributes including yield of triticale (Rathore and Singh, 1975; Patil and Bathkal, 1975). Higher yields, due to higher 1,000 grain weight and grains per ear were obtained with frequent application of irrigation Singh (1978). The present findings are also in agreement with those of Aggarwal and Yadava (1978); Jana and Sen (1978); Joshi and Singh (1983); Misra and Chaudhary (1985); Aggarwal and Sinha (1987); Gupta and Patil (1987); Prasad *et al.* (1987) and Patra (1990).

On comparing the number of irrigation in both irrigants it was noted that under ground water I_4 recorded maximum grain yield while only three irrigations (I_3) produced maximum grain yield under treated effluent irrigation (Experiment 2). It may be because of the higher values of RWC in treated effluent than in ground water (Table 39). This increase in RWC may be due to the increase in chemiosmotic potential through the accumulation of organic acids, sugar and organometallo complexes. In addition, the treated effluent may have an indirect effect through the changes in soil structure permeability porosity and aeration due to the presence of oil and grease (Mahida, 1981).

In Experiment 3 it was noted that potassium application together with treated effluent increased the yield of triticale at all the irrigation levels. The optimum potassium dose, i.e. K_{60}, together with effluent showed an increase of 36.05% over K_0 (Table 66). Potassium supply increases the leaf area and also the amount of chlorophyll and both these factors could bring about higher net assimilation. In connection with the role of potassium in osmoregulation and stomatal movement it is noteworthy that leaves with a better K supply have higher succulence and a slightly longer leaf area duration providing assimilates for an extended period for grain filling. In addition, K nutrition stimulates yield of cereals primarily by increasing grain size.

Water deficits influence the yield of triticale by decreasing the yield components, such as, the number of ear bearing tillers, number of grains per ear and grain weight. The leaf area is reduced not only at the time of differentiation but also after anthesis. The reduction in leaf area can reduce yield of the crop under water stress.

In Experiment 4 also, Delfin exhibited superiority over the wheat check in terms of yield attributes and final yield per hectare. Triticale recorded 6.6% increase in yield over wheat. This increase in yield was mainly due to increased yield attributing paramaters as mentioned earlier.

Treated effluent supplemented with fertiliser increased the vegetative and reproductive growth as is evident from the increase in straw and grain yield (Tables 82,83). The sub-plot treatment $N_{120} P_{60} K_{60}$ together with effluent gave the maximum grain yield through its beneficial effect on most of the ear characteristics (Tables 76-80). Thus, ear number and ear weight per plant, ear length, spikelet number and grain number were increased most by this treatment their cumulative effect manifesting itself in the higher grain yield. In fact, the aim of every cereal breeder is to maximise these ear characteristics and finally yield itself. There is sufficient published information to show that higher grain yield was obtained mainly, if not entirely, due to the beneficial effect of balanced fertilisers on ear characteristics. Of these, mention may be made of Samiullah (1971), Ahmad (1975), Qaseem (1975) and Naqvi (1976) on barley; Singh (1964), Garg and Tomaria (1976), Sharma and Kumar (1972) and Langer and Liew (1973) on wheat and Barnett *et al.* (1973) Reddy and Lal (1976); Inam (1978) and Ashfaq, (1983 b) on triticale.

5.6 Grain quality

Plants draw from the soil a number of essential mineral salts and water which they utilises not only for their growth and yield but also for the quality of their produce. If any of them is deficient, the quality of the crop is likely to be affected as they are involved in the biosynthesis of various metabolities.

In Experiments 1 and 2, contrary to growth and yield, crops grown under treated effluent contained less carbohydrate, protein, and lysine compared to ground water. The lower levels of carbohydrate, protein and lysine may be due to the increased grain yield as a result of "dilution effect". This is a phenomonon commonly associated with bumper harvest in many crops. Similar results were also found by Day and Tucker (1977) where they reported less protein in sorghum grwon with wastewater irrigation and Veer and Lata (1987) who reported low levels of protein, soluble nitrogen, reducing and non-reducing sugars under effluent application.

In Experiment 1, it was observed that triticale showed superiority over wheat regarding nutritional value as its grain was richer in protein, lysine and carbohydrate content. The bio-logical value of protein depends upon the essential amino acid of which lysine is the most important. Being an intergeneric hybrid of wheat and triticale combines high total protein content of wheat and high lysine content of rye (Hulse and Spurgeon, 1974). Higher content of protein in triticale has also been reported by Villagas *et al.* 1968 and Bronwer, 1977. This is also in conformity with the findings of Sisodia (1971), Villegas (1973), Demir *et al.*, (1978), Gill and Sandha (1980), Alvi (1984) and Moinuddin (1987) on triticale. Delfin contained maximum protein, carbohydrate and lysine content followed by Driera. Delfin also produced highest protein and carbohydrate per hectare. Wheat showed protein content at par with TL-419 and carbohydrate content with Driera. But in the case of lysine, wheat performed poorest. While considering the protein and carbohydrate yield per hectare, it was noted that wheat (HD-2204) almost caught up with Delfin. This was due to the higher grain yield wheat compared to that of Driera and TL-419. These findings are also in agreement with those of Moinuddin (1990 a, b).

In Experiment 2 and 3 (Table 49,69), three irrigations proved optimum for carbohydrate percentage in grains while no irrigation and one irrigation were at par. Protein and lysine content were optimum under four irrigations (Experiment 2) while three irrigations were found optimum in Experiment 3. Like the grain yield, protein and carbohydrate yield per hectare showed almost a linear increase with the increase in irrigations. These results are in agreement with the finding of Yadava and Srivastava (1986) who noted a significant increase in protein yield with increase in irrigation. Similar effect on grain protein content of triticale by the irrigation treatment were reported by Bakhshi *et al.* (1975). Patil and Khuspe (1978) also reported higher production of protein with higher levels of irrigation which was contributed mainly due to higher dry matter production. In general, the values of grain quality characteristics were comparatively lower with less irrigation or no irrigation (water stress). Levitt (1980) suggested that water stress resulted in wilting which may speed up the aging of leaves by decreasing the protein synthesising power.

Potassium application in Experiment 3 enhanced the protein and carbohydrate content of grain but the lysine content was decreased (Table 63-

65). It is well known that potassium application not only facilitates the uptake and assimilation of nitrogen into simple amino acid and amides (Sodek *et al.,* 1980), but also favours peptide synthesis leading to protein synthesis (Evans and Sorger, 1966).

Potassium is often described as the "quality element" for crops production. With a shortage of K, photosynthesis, respiration, translocation and a number of enzymes system may be disrupted, thereby causing reduction in crop quality. Mengel et al. (1981) reported an indirect influence of K on grain protein formation through amino acid translocation from vegetative plant parts to the grain, which favoured synthesis of gluten and prolamine. In addition, K promotes N absorption and translocation of assimilates to the grain as well as formation of proteins.

In Experiment 4 triticale cultivar Delfin exhibited higher protein, carbohydrate and lysine content compared to wheat (HD-2204), confirming the superiority of this triticale variety over wheat noted earlier.

The importance of NPK as plant nutrients is well established. They either enter into the composition of one or the other of a large number of important cell constituents maintain turgor and influence enzymes that play a key role in metabolic activities responsible for yield and quality (Hewitt, 1963; Delvin, 1981). It was noted that there was a linear increase in protein and carbohydrate content with increase in fertiliser dose but the reverse was true in the case of lysine content. In cereals, including triticale, positive correlation of applied NPK to protein content is well established as reported by a number of researchers, including McNeal and Davis (1954), Eck *et al.* (1963), Singh and Gupta (1969), Afridi and Samiullah (1973) in wheat and barley and Kalra and Dhiman (1979), Bishnoi and Mugwira (1980), Alvi (1984), Yadava and Srivastava (1986) and Moinuddin *et al.* (1990 a, b) in triticale. The application of NPK increase the grain protein but at the cost of its lysine content. The inverse effect of NPK application on the concentration of lysine in the grain protein is in agreement of the results on triticale of Larsen and Nielsen (1966), Bhaid *et al.* (1969) Srivastava *et al.* (1971), Kalra and Dhiman (1979), Yadava and Srivastava (1986).

CHAPTER 6

SUMMARY

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The importance of the problem "Effect of treated oil refinery waste water on physiomorphological characteristics of triticale" has been considered in brief. Justification has been put forward for undertaking the present work emphasising the originality of the problem (Chapter 1).

The available literature pertaining to waste water and its use in irrigation, water stress, role of potassium and brief account of progress made regarding triticale cultivation has been reviewed with special reference to the work done in India (Chapter 2).

The details of the materials and methods employed for the four split-plot field experiments conducted during the rabi seasons of 1988-91 have been given with relevant soil and water analysis data (Chapter 3).

In brief, Experiment 1 was conducted to study the effect of treated effluent on germination, growth, yield and quality of three vaarieties of triticle (Delfin, Driera and TL-419). Ground water and wheat (HD-2204) were taken as checks.

Experiment 2 was conducted on one variety of triticale, selected on the basis of its better performance in Experiement 1, to study the effect of five levels of treated effluent irrigation (I_0, I_1 I_2, I_3 and I_4) on its growth, yield and quality taking ground water as check.

Experiment 3 was conducted during the following rabi season, on growth, yield and quality of triticale cultivar Delfin. The aim of this field trial was to study the effect of various levels of applied potassium (0,30, 60, kg K/ha) in ameliorating the adverse effect of induced water stress taking four levels (I_0,I_1 I_2, and I_3) under treated effluent irrigation.

Experiment 4 was conducted simultaneously with Experiment 3 on Delfin and HD - 2204. The aim of the Experiment was to study the comparative effect of various doses of fertiliser ((N_0,P_0 K_0, N_{60} P_{30} K_{30},N_{90} P_{45}, K_{45} and N_{120} P_{60},K_{60}) and treated effluent irrigation on growth, yield and quality of the selected triticale and wheat cultivars.

The data, mostly found significant at $P<0.05$ on statistical analysis according to design of each experiment, have been considered in detail (Chapter 4).

The important results have been discussed in the light of the findings of earlier workers (Chapter 5).

The following conclusion were drawn:

1. Germination was not affected due to effluent irrigation.
2. The treated refinery effluent proved better than ground water for irrigation purpose and almost all the growth and yield parameters responded positively.
3. Treated effluent increased the grain yield of all the triticales and

wheat.

4. Delfin outyielded the other two cultivars of triticale and the wheat check under effluent as well as ground water irrigation.

5. Water stress in general decreased all the growth and yield parameters including the final grain yield.

6. Almost all the growth and yield parameters were equally affected by I_3 and I_4 under treated effluent irrigation. On the other hand, four irrigations (I_4) gave the maximum values under ground water irriga tion.

7. Treated effluent gave higher values of relative water content RWC and proline compared to ground water.

8. A linear decrease in RWC from tillering to milky grain stage was observed while linear increase in RWC was found with increase in potassium doses and irrigation levels.

9. A linear decrease in proline content was noted with increase in irrigation while potassium application increased the proline content.

10. The fertiliser dose N_{120} P_{60} K_{60} gave the optimum values for all growth, yield and quaqlity parameter, except lysine content.

11. In general, triticale proved superior to wheat in grain quality. Among triticale Delfin had maximum protein, carbohydrate and lysine content.

12. Contrary to the growth and yield parameters, effluent application had an adverse effect on grain quality, giving lower protein, carbohy

drate as well as lysine content.

The present summary is followed by relevant references and an appendix giving the details for the preparation of various reagent used in the course of the experiments.

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APPENDIX

APPENDIX

A Reagents for plant analysis

1. Proline

Acid ninhydrin

It was prepared by warming 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 5M orthophosphoric acid (407 ml/l) with agitation until dissolved. It was stored at 4°C for 24 h.

2 Carbohydrate

1.5 N sulphuric acid

20.4 ml concentrated sulphuric acid was diluted with distilled water and the volume made upto 500 ml.

3. Protein

i) Reagent A : 2% sodium carbonate + 0.1 N sodium hydroxide (1:1)

ii) Reagent B : 0.5 % copper sulphate + 1% sodium tartarate (1:1)

iii) Reagent C : Alkaline copper sulphate solution. It was prepared by mixing 50 ml of reagent A with 1 ml of reagent B.

iv) Reagent D: Carbonate copper sulphate solution. It was prepared like reagentC, except for sodium hydroxide.

v) Reagent E: 1N acid Folin reagent - 100 g of sodium tungstate and 25 g of sodium molybdate were dissolved in 700 ml of water and was kept in a 1500 ml flask. Then, 50 ml of 85% phosphoric acid and 100 ml of concentrated hydrochloric acid were added. The flask was connected with a reflux condenser and boiled gently on a heating mantle for 10 h. At the end of the boiling period, 150 g lithium sulphate, 50 ml water and 5 drops of liquid bromine were added to the flask. The reflux was removed and solution was boiled for 15 min to remove excess bromine. After cooling it was diluted to 1,000 ml with distilled water.

The strength of this acidic solution was estimated by titrating it with 1 N solution of sodium hydroxide, using phenolphthalein as an indicator. It was then diluted to the required strength (1N).

(vi) 1N sodium hydroxide solution : It was prepared by dissolving 4 g sodium hydroxide in distilled water and finally making up the volume to 100 ml.

4. ***Lysine***

i) Papain solution. It was prepared by dissolving 4 mg of papain per ml of 0.03 M phosphate buffer (pH 7.4). The solution was filtered before use.

ii) 0.05 M carbonate buffer (pH 9.0)

iii) 0.05 M borate buffer (pH 9.0)

iv) Copper phosphate suspension : This was prepared as follows :

Solution A : 2.8 g of $CuCl_2.2H_2O$ was dissolved in 100 ml distilled water.

Solution B : 13.6 g of $Na_3PO_4.12H_2O$ was dissolved in 200 ml distilled water.

Solution A was poured into solution B with swirling and then the mixture was centrifuged at 3,000 rpm for 5 min to collect the precipitate. The precipitate was washed three times in 15 ml of 0.05 M borate buffer and the pellet centrifuged, after each suspension. After the third washing, the pellet was suspended in 80 ml of borate buffer.

v) 2-chloro-3,5 dinitro pyridine solution : This solution was prepared fresh just prior to its use. To obtain, 1 ml of methanol was added to 30 mg of 2-chloro 3,5 dinitro pyridine.

vi) Mixture of amino acids

Cystine	20 mg	Phenylalanine	40 mg
Methionine	20 mg	Valine	40 mg
Histidine	30 mg	Arginine	50 mg
Alanine	30 mg	Serine	50 mg
Isoleucine	30 mg	Aspartic Acid	50 mg
Threonine	30 mg	Glutamic acid	300 mg
Tyrosine	30 mg	Leucine	80 mg
Glycine	40 mg	Proline	80 mg

100 mg of amino acid mixture was dissolved in 10 ml of carbonate buffer.

B. Reagents for water analysis

5. Biochemical oxygen demand (BOD)

i) Manganese sulphate solution : 40 g of manganese sulphate was dissolved in distilled water and final volume was made up to 100 ml.

ii) Alkaliazide reagent : 50 g of sodium hydroxide and 13.5 g sodium iodide were diluted to 100 ml with distilled water. 1 g of sodium azide dissolved in 4 ml of distilled water and mixed to above solution.

6. Chemical oxygen demand (COD)

i) Standard potassium dichromate solution 0.25 N : 12.259 g $K_2Cr_2O_7$ was dissolved in distilled water and final volume was maintained to 1,000 ml.

ii) Standard ferrous ammonium sulphate solution 0.1 N: 39 g of $Fe(NH_4)_2(SO_4)_2\,6H_2O$ was dissolved in distilled water. To this 20 ml of concentrated sulphuric acid was added and finally volume was maintained to 1000 ml.

iii) Ferroin indicator solution : 1.485 g 1,10 - phenanthroline monohydrate, together with 495 mg $FeSO_4.7H_2O$ were dissolved in distilled water and finally volume was maintained to 100 ml.

7. Total hardness

i) 0.01M ethylene diaminetetra acetic acid : 3.723 g EDTA was dissolved in distilled water and diluted to 1,000 ml.

ii) Eriochrome Black T indicator : 0.5 g dye was mixed with 100 g of 2,2,'2" nitrilotriethanol.

8. ***Calcium***

Ammonium purpurate : 150 mg dye was dissolved in 100 g ethylene glycol.

C Reagents for soil analysis

9. ***Organic carbon***

i) 1N potassium dichromate : 49.04 g potassium dichromate was dissolved in distilled water and finally the volume was made upto to 1,000 ml.

ii) N/2 ferrous ammonium sulphate : 196 g of hydrated ferrous ammonium sulphate ($FeSO_4(NH_4)_2$ SO_46H_2O) was dissolved in distilled water, to this 20 ml of concentrated sulphuric acid was added and finally volume was made upto 1,000 ml.

iii) Diphenyl amine indicator : 0.5 g diphenyl amine was dissolved in a mixture of 20 ml of water and 100 ml of concentrated sulphuric acid.

10 ***Available phosphorus***

i) Olsen's reagent : 42.0g of sodium bicarbonate was dissolved in distilled water to give 1,000 ml of the solution. The pH was adjusted to 8.5 with the addition of small quantity of sodium hydroxide.

ii) Dickman and Bray's reagent : 15 g of ammonium molybdate was dissolved in 300 ml of warm water (about 60°C). Then it was cooled and filtered. To this 400 ml of 10 N hydrochloric acid was added and finally the volume was maintained to 1000 ml.

iii) Stannous chloride solution : 10 g of crystailine stannous chloride was dissolved in 25 ml of concentrated hydrochloric acid by warming and stored in amber coloured bottle. This was only 40% stannous chloride solution. Just before use 0.5 ml was diluted to 66 ml of distilled water.

iv) 7N sulphuric acid ; 19.6 ml concentrated sulphuric acid was added to double distilled water and the final volume was made upto 100 ml.

11. Available potassium

i) Ammonium acetate solution (neutral and normal) : Solution of 2N acetic acid (glacial) and 2N ammonium hydroxide was prepared by titration with standard alkali and acid and equal volumes of the two were mixed in a large beaker. On cooling pH was adjusted to 7.0 with acetic acid.

12. Calcium

i) 0.01 N EDTA solution : 2.0 g of ethylene diamine tetra acetic acid was dissolved in distilled water and final volume was made upto 1,000 ml.

ii) Murexide indicator :0.2g ammonium purpurate was mixed with 40g of powdered potassium sulphate.

13. ***Cation exchange capacity (CEC)***

i) 0.1 N sodium hydroxide solution : 4 g of sodium hydroxide was dissolved in distilled water and the final volume was made upto 1,000 ml.

14. ***Sulphate***

Conditioning reagent ; 50 ml glycerol was mixed in a solution containing 30 ml concentrated hydrochloric acid +300 ml distilled water + 100 ml of 95%ethyl alcohol and 75 g sodium chloride.

15. ***Chloride***

i) Potassium chromate indicator : 50 g of potassium chromate was dissolved in distilled water. To this silver nitrate solution was added until a red precipitate was formed. After overnight stand it was filtered and diluted to 1,000 ml with distilled water.

ii) Standard silver nitrate titrant (0.0141N) : 2.395 g silver nitrate was dissolved in distilled water and it was diluted to 1,000 ml.

16. ***Carbonates and bicarbonates***

i) Phenolphthalein indicator ; 0.25% solution was made in 60% ethyl alcohol.

ii) 0.01N sulphuric acid : 0.272 ml sulphuric acid was diluted in distilled water and final volume was made upto 100 ml.

iii) Methyl red indicator : 0.5% solution was made in 95% alcohol.

17. Nitrate nitrogen

Phenol disulphonic acid : This was prepared by taking 25 g pure phenol (C_6H_5OH, crystal white) in conical flask (500 ml) to which 150 ml concentrated sulphuric acid (nitrate free) and 75 ml fuming sulphu ric acid (nitrate free) were added and kept on boiling waterbath for 2 h covered with watch glass. After cooling it was stored in amber coloured bottle.